

LABORATORY DIRECTIONS

IN

GENERAL ZOOLOGY

BY

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FOR USE IN THE FIRST COURSES IN ZOOLOGY
IN THE UNIVERSITY OF MINNESOTA

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By CHARLES P. SIGERFOOS

PREFACE TO FIRST EDITION*

These Laboratory Directions are intended to serve as a guide for the manipulation of material in the laboratory, in the courses in first-year Zoology, and are not intended to serve as a text-book. The student is expected to come into the laboratory with a specific knowledge of the work to be done and a general knowledge of the forms to be studied.

It should be kept in mind constantly that the primary object of laboratory work is to train the hands, eyes, and mind by the painstaking study of objects at first hand. Drawings are secondary in importance to the manipulation and study of material, but they are essential in inciting the student to careful study; in fixing points in his mind; and in showing the instructor the quality of the work done. While drawings may not be artistic, they must be accurate and neat, for there can be no profit in making careless drawings.

C. P. S.

University of Minnesota, October, 1902.

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*The excellent figures first used in the 1909 edition were executed by Dr. G. W. Snyder. Those added from time to time in later editions were drawn by the artists indicated in the legends accompanying the later figures.



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LABORATORY DIRECTIONS IN GENERAL ZOOLOGY

CHAPTER I

INTRODUCTION

The first course in the Department of Zoology is a course in General Zoology and is fundamental to, and prerequisite for all of the more advanced courses in the department. It is intended to cover the general principles of structure, physiology, embryology, heredity, and evolution of animals.

The work is partly in the classroom, for lectures, quizzes, and discussions; partly in the laboratory for the careful first-hand study of animal life. While the first-hand knowledge and the discipline thus derived are invaluable, the laboratory work is intended to be of special value as illustrating the "scientific method." It will require all of your powers of attention, concentration, and judgment. Special attention must be paid to accuracy, neatness, and system. Each student should work independently, although comparisons of results are desirable from time to time.

LABORATORY NOTES

Most of the laboratory notes are kept in the form of labeled drawings or "figures," made upon firm, unruled, linen paper with a sharp, hard, drawing pencil. Drawings may not be artistic, but they must be clean, neat, clear-cut, and accurate. In the beginning, at least, you may find it necessary to use faint trial lines in making your drawings. When finished, however, all irregularities should be eliminated and the essential structures should stand out in even, clear-cut, tangible lines. The drawings should be large enough to include all of the essential features clearly. Each drawing upon a sheet or "plate" should stand out clearly to itself. The drawings should not be crowded together. While the most essential

drawings are designated in the Directions, each student will often find it desirable to make independently simple sketches in addition. Unless otherwise announced, the laboratory notes are left at your desk at the end of each period and you should plan your work to have it completed.

Each drawing is called a "figure," and the figures are numbered consecutively through the course. Under each figure are placed in Arabic numeral its number, and the "legend" or main description of the object drawn. In addition, radiating lines are run out from the features of the drawing and the names neatly printed or written. The lines may radiate out from the drawing in any direction, but the labels are horizontal. The labels should be large enough to be easily read, but not large enough to become too conspicuous.

The accompanying page illustrates three sample types of lettering. You should practice with them and decide upon one of the three which you wish to follow consistently through the course.

Each sheet of paper, whether containing one or several drawings, is called a "plate." The plates are numbered consecutively through the course, in Roman numerals in the right upper corner of the plate. Each plate should also have your name and seat number in the left, lower corner. Study carefully the accompanying plate to get the technique of drawing, labeling, etc.

The laboratory notebooks will be called in at the middle and at the end of each quarter. All of the plates should be revised, arranged in proper order, and in every way be in good condition. At the beginning of the book should be a table of contents or "index," giving the plate and figure numbers, and the main legend of each figure. The work of the whole course, with an index at the beginning of the book, will be called in at the end of the course.

GENERAL LABORATORY ROUTINE

You will be assigned a locker in the hallway and should

TYPES OF LETTERING for use on laboratory drawings

a b c d e f g g h i j k l m n o p q r s t u v w x y z
 A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
 1 2 3 4 5 6 7 8 9 0

Use guide lines:— proportion 2-3

a b c d e f g g h i j k l m n o p q r s t u v w x y z
 A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
 1 2 3 4 5 6 7 8 9 0

This type of informal lettering is very quick and can be very neat.
 Guide only with a straight-edge held in place while lettering.—

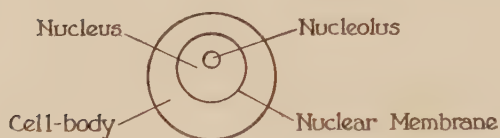


Fig. 1.— Ideal cell (immature egg of starfish,
as seen with low power)



Fig. 2.— Red blood cell of salamander,
as seen with low power



Fig. 3.— Red blood cell of salamander,
as seen with high power

John Doe

No. 26

Fig. 1—Sample plate, to show the method of making, arranging, and labeling drawings. This plate, if increased in size one half would show your first day's work in the laboratory. (Drawn by Jean Hirsch.)

provide your own padlock. You will be held strictly responsible for having your own full equipment in good condition every day. Your books, instruments, etc., should bear your name, number, and section.

Your place should be left in good condition when you leave. Slides should be removed from the microscope and placed in their trays. Following dissections, unfinished specimens should be labeled with your name and number, and left in the receptacles for future use. Solid waste should be thrown into the waste cans, **not in the sinks**, and your dissecting pan rinsed and left clean.

The laboratory will be open Saturday afternoons, 12:30 to 3:30, to do work which has been missed, finish work not completed during the regular period, repeat work not properly done, or supplement the work regularly required of all students. Such work may not be postponed indefinitely, but must be done at the first opportunity. Plates so made should be rubber-stamped, and O. K.'d by the instructor in charge.

THE MICROSCOPE AND ITS USES

Inasmuch as about half of the laboratory work in General Zoology involves the use of the microscope, it is well at the beginning to get acquainted with its purposes, construction, care, and manipulation.

Examine your microscope and identify its main features by means of the accompanying illustration, as follows: "Low power objective," shorter, with larger lenses, for lower magnification; "high power objective," longer, with smaller lenses, for greater magnification; "nose piece," for quickly changing from one objective to the other; "eyepiece," next the eye in the upper end of the tube; the flat rubber "stage," on which is placed the slide to be studied; "stage clips" for holding the slide firmly in place; a double-faced "mirror," below the stage for illuminating the object by reflecting the light from the sky through the object and microscope to the eye; "iris diaphragm" below the stage, for regulating the amount of light; "Abbe

condenser," a lens in the center of the stage for concentrating the light; "coarse adjustment," for bringing the object into general focus; "fine adjustment," for delicately focusing upon

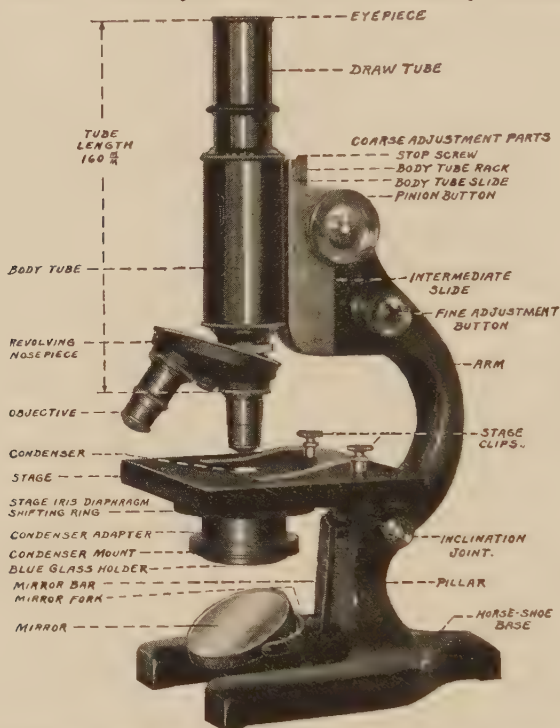


Fig. 2—Figure to show the principal parts of the compound microscope. (Courtesy of the Spencer Lens Co.)

and through the object, especially when using the high power; "arm," to be used always in handling the microscope.

The primary purpose of the microscope is to enable one to study the structure of minute objects, invisible or poorly seen with the unaided eye. Its quality depends, therefore, in largest measure, upon the objectives and eyepiece for magnification, especially the objectives. All of the other parts are accessory to this main purpose. All examinations are first made with the low power in order to find easily the desired

object for study; to get a general survey of it; and, if further study with the high power is desired, to bring into the center of the field the part desired for further study. The change from low to high power is easily made by means of the revolving nose-piece, which should be turned till it clicks. When changed, the object should be nearly in focus and in the center of the "field" for the high power. The "magnification" of a microscope is expressed in "diameters." With the low power of your microscope it magnifies about 80 diameters; with the high power, about 350.

Proper illumination of the object is of vital importance. Poor results and eye-strain often result because of improper lighting of the object. This depends upon proper use of the mirror in getting light from the proper source and, especially, of the iris diaphragm for controlling the amount of light. By means of the mirror (usually the plane one is used) light from the sky (usually) is reflected through the object and the microscope to the eye. Depending upon the brightness of the sky, the nature of the object to be studied, the objective used, and the eye of the observer, the light must be regulated constantly to just the right amount required at the time to bring out best the structure of the object studied.

The objectives must be at the proper distance from the object—must be "in focus." Rapid shifting is done by means of the **coarse adjustment**. Accurate focusing, especially when using the high power, is done by means of the **fine adjustment**. All objects to be examined have thickness, of course, and the structural features within an object are examined by **constant focusing**. The image of an object seen through a compound microscope is "reversed"—right and left side of the object become left and right in the image, top becomes bottom, etc.

Each microscope has minor peculiarities. You should acquaint yourself with these in the microscope assigned to you.

Microscopic preparations are called "slides." The object for study is put upon the slide and covered with a "cover glass." Some objects (Protozoa, some tissues) are examined alive in water or other aqueous solution. Most objects, how-

ever, have been passed through many stages in their preparation and are made into permanent "slides," sealed in some resinous material between the slide and cover glass. Especially important is it that the object has been "stained" with one or more dyes or stains to bring out more clearly the various structural features, especially the nucleus of cells and its contents. The color of the object, therefore, is usually purely artificial. The stains most frequently used are carmine (pink) and hematoxylin (purple) for staining the nucleus.

ROUTINE FOR THE USE OF THE MICROSCOPE

1. Place your microscope straight in front of you, with the arm toward and the stage away from you. See that the "drawtube" is drawn out to 160 millimeters, as shown in the figure of the microscope.

2. Turn on the lower power objective and, looking to one side of the microscope, run down the objective to within a quarter inch of the stage of the microscope.

3. Turn the flat side of the mirror toward the light and, looking into the microscope, regulate the light by means of the iris diaphragm till you have a uniform, clear, circular "microscopic field."

4. Place the object on the slide in the center of the stage and **focus up** till the object is clear—"in focus." Focus carefully and regulate the light by means of the diaphragm till the object is most distinct. **Never focus down with the coarse adjustment**, for you would be in danger of ruining the slide.

5. With low power, find the best part of your preparation, get a general idea of it, and bring the best part into the center of the field for further examination with the high power.

6. Turn on the high power, regulate the light and focus carefully and constantly. Complete your study.

7. When through with any study, turn on the low power, remove the slide, and place it in the tray where you found it.

8. Carefully return the microscope to its locker, unless otherwise directed.

GENERAL PRECAUTIONS IN THE USE OF THE MICROSCOPE AND SLIDES

1. The microscope is to be used as an instrument of precision and should be handled accordingly. If at any time it does not seem to be working properly, call it to the attention of your instructor.

2. The glass parts of the microscope must not be touched with the fingers.

3. You should habitually use your left eye for microscopic work, leaving your right eye free for drawing and other work. As soon as possible, accustom yourself to keeping your right eye open while using your left eye for microscopic work.

4. All objects are first found, examined, and centered with the low power.

5. Slides, when not in use, must be kept in the trays.

6. When you leave, your place should be left tidy and in good condition.

EQUIPMENT NEEDED FOR GENERAL ZOOLOGY

Text-book, to be assigned.

"Laboratory Directions in General Zoology," 1928 Edition—Sigerfoos.

Laboratory Notebook, filled with unruled, heavy linen paper for drawings.

300 page "record" notebook for lecture notes.

4H "Kohinoor" or "van Dyke" drawing pencil. Eraser.

A pad of fine emery paper for pointing drawing pencil.

Small ruler, graduated in millimeters.

Dissecting instruments. These must be in good condition and include coarse and fine scissors; coarse and fine (with curved point) forceps; scalpel; two mounted needles.

Hand towel.

Padlock for locker.

Colored pencils, with at least red, green and blue colors.

CHAPTER II

PHYLUM PROTOZOA

THE PROTEUS ANIMALCULE

Amœba proteus and *A. polypodia*

Amebas are not always easily obtained, but usually representatives of one or more species may be found in the material which collects at the sides of large aquaria, and in the scum at the surface of dishes in which pond plants have decomposed for two or three weeks. Our specimens for study are usually raised by introducing material containing amebas into dishes with hay in water, covered with sphagnum moss. In this they may multiply rapidly and after two weeks or more, become abundant. There may be several species, but especially *A. proteus* and *A. polypodia*. *A. proteus* has long been a classic object for study and is especially good because of its large size, its activity, and the ease with which its parts may be seen. The word "ameba" is almost universally used as the vernacular for these and similar forms. Also, the species "*Amœba proteus*," as used here, is now recognized to include three or more species.

Mount some material under a large cover-glass and let the preparation stand for a few minutes until some of the animals have crawled out from the detritus of the preparation. The stained specimens in permanent slides, both whole mounts and sections, are used to supplement the study of the living specimens, especially for the nucleus.

With low power, look for amebas in the living material. Pick out an active specimen in a clear field, and study carefully with high power. Note the irregular and changing outline of the animal, extended into the pseudopodia which are constantly changing in position, number, size, and form. By

ameboid movement

ectosarc

endosarc
vacuoles - food & contractile

IN GENERAL ZOOLOGY

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means of these it performs its locomotion by **ameboid movement**.

Make five or six 2-inch outline drawings at intervals of a minute to show the changes in form. Omit all details of internal structure. By arrow-heads indicate the direction in which the protoplasm is flowing in the various parts of the animal, at the time each figure is drawn.

Now study the structure of a favorable specimen in detail, by means of the high power. Get first a sharp idea of the animal as a **unicellular animal**, with the cell-body composed of **cytoplasm** externally as the main mass; and the small oval, granular **nucleus** internally. Carefully examine the nucleus also in the specimens stained with carmine in the prepared slides, and especially in the sections, noting that it is closely packed with the granular **chromatin**.

Note the differentiation of the cytoplasm into an outer thin, clear, firmer pellicle, the **ectosarc**, and an inner granular, more liquid **endosarc**; the **contractile vacuole**, a clear pulsating vesicle in the endosarc, which slowly disappears and reappears with a more or less regular **rhythm** (observe during three or four pulsations and make note of the frequency); the **food vacuoles**, containing diatoms and other food particles, and varying in number, size, color, and character with the nature of the food **ingested**. Note that in ameba there is an entire absence of differentiation into regions of the body,—any part may become temporarily anterior or posterior, right or left, etc.

Make a large figure (four inches or more in diameter) to show the details of structure. Also, pick out a good section and draw, putting in accurately the granular chromatin of the nucleus. You should get from this section a sharp idea of ameba as a unicellular animal, with a cell-body containing a nucleus.

Amebas ingest particles of food by flowing around them during their ameboid movement, and egest indigestible waste particles by flowing away from them. Try to observe these

processes. What physiological processes have you observed during your study of ameba?

If your preparation contains individuals of other species of amebas, study the living specimens in the same way as *A. proteus*.

A NON-COLONIAL FLAGELLATE

Euglena viridis

This form has great interest for us, because it is one of the border-line forms between the plant and animal kingdoms, possessing some of the features characteristic of each. Though very small (averaging perhaps one three-hundredth of an inch in length), it is at times so abundant as to give a bright green color to pools of water. Some related forms are not green, but show more clearly the flagellum and will also be given out, so far as living material is available. The stained specimens of *Euglena* should also be examined, especially for the nucleus.

In the living material of *Euglena*, note its form, color, ^{forward direction} direction of motion with reference to the light. In addition to its forward locomotion by means of its flagellum, the organism may "worm along" by changing its form. Observe any such specimens, and make simple outline drawings to show the normal form, and the changes in shape. Examine a favorable specimen in detail, noting flagellum (better seen in specimens which have been killed); nucleus, with nucleolus, in center; pigmented eye-spot; near the latter, the contractile vacuole and the gullet; the chloroplasts, containing the chlorophyll (the green coloring substance of plants). *Euglena* may encyst for passing over unfavorable periods, and in this condition may divide into two, or sometimes into four. Look for encysted specimens.

Draw a 4-inch detailed figure showing structure; also, so far as you have studied, simple outlines of encysted specimens.

photo to specimen -
respond to light positively

COLONIAL FLAGELLATES**Eudorina sp., and Volvox Sp.**

The green flagellates, including *Euglena* (better, *Chlamydomonas*), *Gonium*, *Pandorina*, *Eudorina*, *Volvox*, show consistent advancement in colonial organization and in sexual reproduction. They portray to us something of what may have been the early evolutionary history in the development of cell aggregates and of sex in the animal kingdom. *Chlamydomonas* is one cell, with two flagella; *Gonium* a flat plate of 16 such cells; *Pandorina* a solid spherical colony of 16 cells; *Eudorina*, a hollow colony of 16 or 32 cells; *Volvox*, a large hollow colony of thousands of cells, specialized into somatic and reproductive cells.

Eudorina sp.

Eudorina is a small, hollow spherical colony of 16 or 32 cells, each of which is very similar to *Euglena*, but with two flagella. The colony is surrounded by a thick gelatinous envelope, through which the flagella project and, by their combined action, cause a rotating forward motion of the colony. If you have living specimens, note the **character and direction (with reference to the light) of the movement**; the **form of the colony**; the **gelatinous envelope**; the **32 cells arranged as five girdles with 4-8-8-8-4 cells**; flagella and other features of each individual so far as you can. If you have only preserved slides, make out all you can.

Make a 2-inch drawing to show all you have made out of the structure, showing the details of one or two cells, and the outlines of the others.

Volvox Sp.

Volvox is a large spherical colony composed of several hundred to several thousand (depending on the species) indi-

vidual cells, specialized into **somatic cells**, which form the wall of the sphere; and **germ cells**, which lie in the gelatinous material which fills the cavity of the sphere.

The somatic cells are similar to *Euglena*, but with two flagella instead of one, and are connected together by means of delicate strands of protoplasm.

The germ cells are derived by the enlargement and specialization of some of the surface cells, and are of two types: 1, **parthenogonidia**, usually two or three to a dozen or more, which develop without fertilization and, by repeated division into 2, 4, 8, etc., form the daughter colonies lying in the cavity of the mother colony. 2, **sex cells**. Depending on the species, both male and female cells are formed in the same or in separate colonies. The **egg cells** grow very large, and become typical ova. Each primordial **male cell**, by repeated division into 2, 4, 8, etc., forms a packet of 128 sperm cells. Each egg is fertilized by one sperm cell. Then the fertilized egg falls to the bottom, resists and tides over unfavorable conditions, hatches when the conditions again become favorable, and develops into a normal colony.

Make a 3-inch outline drawing of a large colony and the contained daughter colonies, and put in a few of the cells showing their connections with each other. Also, make outline drawings of several colonies, showing daughter colonies of different sizes and numbers. So far as time and materials permit, study and draw stages of the development of the parthenogondia into daughter colonies. Observe the sex cells if they are shown in your specimens.

THE SLIPPER ANIMALCULE

Paramecium caudatum

This animal, both because it is favorable for the study of many fundamental biological problems, and is easily obtained

in unlimited numbers, has been the subject of a large amount of research work in recent years. An infusion of timothy hay which has stood for two weeks or more usually contains thousands of specimens if algae and other "scum" from ponds have been added. Specimens for our study have been taken from a number of culture dishes, so as to show the variety due to differences in origin, conditions of feeding, etc. Part of the living specimens have been stained with neutral red to bring out more clearly the contents of the food vacuoles, but most of them are just as they were taken from the cultures.

Mount a drop of culture containing *Paramecium* under a large cover-glass, supported at one end. Let the preparation rest for a few minutes until some of the specimens have accumulated and come to rest around the edges of the preparation and around the clumps of bacteria and other objects.

Observe first with dissection microscope and low power, noting activities, general form, color, etc. With low power find quiet specimens around the edges of the cover-glass and study under high power. Note the **slipper-like form**. A depression, the **buccal groove**, begins on the left side and terminates in the **mouth**, which is on the **ventral** side somewhat posterior to the middle. Now note **dorsal** and **ventral** surfaces, **right** and **left** sides, and **anterior** and **posterior** ends. Reduce the light and examine carefully with high power. Note the **cilia**, very numerous vibrating filaments, extending everywhere from the surface of the body, and slightly longer at the posterior end.

Draw a surface view from the left side, 3 or 4 inches long, showing only the **external features**.

Pick out a large clear specimen and study the details of internal structure. Note the differentiation of the cytoplasm into an outer firmer, radially striated **cortex** (**ectosarc**), and an inner granular, semi-liquid **medulla** (**endosarc**); the delicate **pellicle** covering the cortex; the **trichocysts**, minute

vesicles in the cortex which cause its striation; the **gullet**, leading from the **mouth** into the protoplasm; the large **macronucleus** and small **micronucleus** (to be studied in permanent, stained preparations), the latter small and indenting the former at one side.

Study the two clear **contractile vacuoles**, situated anteriorly and posteriorly on the dorsal side, best seen in specimens slightly compressed between the slide and cover-glass. They disappear and reappear with a more or less regular rhythm. In each there is a central **primary vacuole** from which, in certain phases of contraction, there radiate six to ten **secondary vacuoles** or canals. Study the rhythm of the vacuoles and make quick drawings to show what you find. Observe several pulsations and estimate and make note of the number per minute. Note the **food-vacuoles**, a more or less definite series of them filled with food particles, and extending from the mouth posteriorly, anteriorly, and again posteriorly to the potential **anus** just posterior to the mouth. You will see the anus only with difficulty when waste is voided.

Draw a 5-inch optical longitudinal section to show the details of internal structure you have made out. Also, so far as you have time, 1-inch figures of cross sections, as you interpret them, through the anterior and posterior vacuoles, and through the nuclei.

Examine a quiet specimen in ventral view and try to observe the **ingestion** of food. The food consists of bacteria, visible as specks under your high power. They are swept down the esophagus till they accumulate into small balls which are gulped into the protoplasm from time to time, every minute or two. The **egestion** of waste through the **anus** just back of the mouth is more difficult to observe.

Reproduction by Fission.—Paramecium will typify for us this simplest and most primitive form of reproduction, found in most of the Protozoa, in which the parent animal di-

vides into two equal daughter animals. Of course, the details differ greatly among the various types of Protozoa.

Look for dividing individuals in the living material, and study the details in the stained slides. The micronucleus divides first into two by **mitotic** division, then the macronucleus by **direct** division, followed soon afterward by the constriction and division of the cell body. There result two equal daughter animals, like each other and like the parent, except in size.

Draw 3-inch figures of three or four stages of fission from the stained slides, including the following: 1, with the micronucleus just divided into two, the macronucleus elongated; 2, with two micronuclei, the macronucleus constricted or dividing; 3, with the macronucleus also divided into two, the cell-body dividing; 4, with the cell-body almost constricted into two, and the division almost completed.

Conjugation.—General Statement.—Conjugation is not primarily a process for reproduction or multiplication, but its purpose is not understood fully at present. During the process, two individuals come together and fuse for several hours along their ventral sides. Intricate changes in the micronucleus take place, after which each animal mutually gives to the other part of its micronuclear material, after which they separate. After separation the **conjugation nucleus** (fused micronuclei from both of the conjugants) undergoes complex changes, and there finally result from each conjugant four small daughter paramecia, each with both micronucleus and macronucleus derived from the original conjugation nucleus. The macronucleus takes no direct part in the process, breaks up into fragments, and finally is absorbed and disappears in the surrounding cytoplasm.

If your living material contains conjugating specimens (two individuals adhering together by their ventral surfaces), study and make an outline drawing of a pair. If not, make a simple drawing from the prepared slides.

The details of conjugation are difficult to study. So far as time and material permit, you may **study and draw the following stages**: 1, a pair of individuals in each of which the micronucleus is still single. 2, in which the micronucleus has divided into two. 3, in which it has divided into four. 4, in which one of the four (the functional one) has divided into halves and the smaller **migratory nucleolus** from each is crossing over to the other individual to fuse with its **stationary nucleus** to form the **conjugation nucleus**; the three other micronuclei are degenerating. 5, in which the individuals have separated from each other and the single conjugation nucleus has divided into two. 6, into four. 7, into eight. 8, four of the nuclei enlarge to become new macronuclei, three degenerate and disappear, and the eighth divides into two micronuclei. 9, the animal divides into two, each with two macronuclei and one micronucleus. 10, in each of the daughters, the micronucleus divides into two, and then the animal divides into two, each with a micronucleolus and a macronucleus. There thus result, finally, from each of the original conjugating individuals, four small daughters, each with a macronucleus and a micronucleus derived from micronuclear material from both conjugants.

Activities and Behavior.—Paramecium, because of the ease of securing an unlimited supply of specimens in pure cultures and because of its large size and very active nature, lends itself beautifully to the study, both of its normal activities and of the fundamental experimental reactions of one of the simplest organisms. As in all physiological experiments, unusual or abnormal individuals will show departures from the normal. Any conclusions must be based on the study of normal specimens. In all of the following observations and experiments, make careful notes of your results, and make simple diagrams to show what you find.

For this work you will need the following equipment:—large slides and long cover-glasses; small glass rods for cover-glass supports; a small bottle containing a pure lot of Para-

medium; a pipette, used only for transferring living specimens to the slide; a second pipette, used only for applying the chemical reagents, and which must be **thoroughly washed after each use**; two square curve-neck bottles for the temperature experiments; a large bottle of tap water for washing the reagent pipette; several small glass containers for the various chemical reagents. To make a mount, stir the specimens in the bottle so as to equalize them and transfer several drops to the center of the slide. Apply the cover, supported with the glass rods crosswise near the ends of the cover. So far as necessary add more specimens at the edge of the cover till the space between the slide and the cover-glass is just filled. The mounts should be made just before they are to be used.

1. Normal activities and response to mechanical stimuli.

In a mount just made, study with dissecting microscope and low power. Note the forward locomotion by swimming by means of the cilia, the animal meanwhile rotating on its long axis so as to progress in a spiral pathway. Observe any specimens that swim against an obstruction, which acts as a **mechanical stimulus**. They plunge against it, draw backwards, turn partly about and again go forwards. The action is repeated, if necessary, till the animal clears the obstruction. This process is spoken of as the "**avoiding reaction**." Put the mount to one side for a quarter hour or more. Then examine again, observing and making note of any grouping of the individuals.

If specimens of *Spirostomum* are available, put some on a slide without a cover. Observe with low power, and apply a mechanical stimulus by tapping sharply on the slide. Make note of the results.

2. Temperature experiment.

The object of this experiment is threefold:—to illustrate the **influence of temperature** upon the activities of animal life; to show the response of an animal to **thermal stimuli**; and to show that an animal chooses an **optimum temperature** if it is free to do so.

Fill the two curve-neck bottles, one with warm water (about 45 degrees C.), the other with ice water. Place them a quarter inch apart, and place a fresh mount of *Paramecium* equally over them. The specimens above the warm bottle will be at a temperature of perhaps 38 degrees C., and those above the cold, of perhaps 10 degrees C. Follow the experiment for 10 minutes or more, and make very careful diagrams and written notes of the results.

3. **Reactions to chemical stimuli.** Perform the following experiments and make note of your results: (a) Use a fresh mount. Run under the edge of the cover-glass a drop of a one-half per cent solution of sodium chloride. As the drop runs under, it forms a semicircular area of essentially pure solution. This reagent is one that has strong power as a stimulus, but slight power for injury. (b) On the opposite side of the same mount run under a drop of very weak solution of acetic acid (one thirty-fifth per cent). (c) At another point, run under a drop of solution containing both of the above reagents, and note the results. (d) Use a fresh mount. Run under a drop of one twenty-fifth per cent solution of mercuric chloride (corrosive sublimate). This reagent is one that stimulates slightly, but injures greatly. (e) At the opposite side of the cover, add a drop of strong picric acid. This causes the discharge of the trichocysts. Observe with low power, and study a demonstration with high power.

4. **Reactions to electrical stimuli.** Apply the two electrodes of a circuit to the opposite sides of a drop containing specimens of *Paramecium* (or better still, *Spirostomum*). Make and break the circuit, and note the results.

THE BELL ANIMALCULE

Vorticella sp.

One or more species of *Vorticella* and vorticella-like forms may usually be found attached to objects in water of all

degrees of impurity, in ponds and in quiet water generally. In the laboratory, dishes with decomposing aquatic plants usually contain many specimens suspended from the surface scum. Mount some material containing specimens. Examine with low power and look for small, bell-shaped creatures which are constantly snapping back and forth, by means of the stalk of attachment.

Note the bell-shaped **body** attached by its apex to the **stalk**. The **peristome** is the rim around the edge of the bell, and encloses the **disc**, which is lifted like a lid at one side over the **mouth**. The mouth leads into the **gullet**, and this into the protoplasm as in paramecium. The **cilia** are limited to somewhat more than a circle, around the edge of the bell.

Note **pellicle**, **ectosarc** and **endosarc**, as in paramecium; a single **contractile vacuole**, opening into the gullet; a long, looped band-like **macronucleus** (to be studied in the stained preparation); the **micronucleus** (difficult to detect, even in prepared specimens); the **food-vacuoles**, each containing balls of minute food particles. In the stalk, note pellicle as an extension of the pellicle of the body; within, the spirally wound contractile muscular **axial fiber** as an extension of the cortex of the body.

Make a small simple outline figure to show an individual in an expanded condition and another after the stalk has contracted. Also, a large detailed figure showing the expanded animal and a small part of the stalk of attachment.

In **reproduction** by fission the bell-shaped body is divided vertically into equal halves beginning at the edge of the bell. One remains on the old stalk, while the other develops a second circle of cilia near its apex, and swims away to establish itself in some new place.

Look for various stages of fission and make outline drawings of two or three.

You may also find **colonies** of one or more kinds of vorticella-like forms in the living material. If so, study the char-

acter of the colonies, activities, etc., and **make general outline figures**. If not, study the form of the colony in the prepared slide and make a general drawing.

A SPOROZOAN

Gregarina sp.

The gregarines, as types of the Sporozoa, infest a great variety of invertebrates, especially the intestine of insects. There are perhaps thousands of species of them. They are very common and abundant in the digestive tract of grasshoppers and crickets in the fall time. The specimens for study are from the intestine of one of the common ground beetles.

Note the arrangement of the individuals in chains of two; the division of the cell into the smaller **protomerite**, and the larger **deutomerite** with the **nucleus**.

Draw

CHAPTER III

ELEMENTARY HISTOLOGY

General Statement.—A few laboratory periods will be given to a study of the elements of animal histology, both for the knowledge of the different kinds of tissues, and to accentuate the “**cell theory**” in biology, i. e., that the animal body among the metazoa is composed of different kinds of cells and their products, modified in form and structure to serve different physiological purposes, and **all derived from the single fertilized egg cell.**

The different kinds of tissues are purposely chosen from different types of animals, to accentuate the universal application of the cell theory. Except in the fresh living specimens, the tissues have been artificially colored or **stained**, the better to demonstrate certain parts, especially the nucleus and its contents. This fact should be kept in mind in studying the prepared slides.

AN IDEAL CELL

The immature, unfertilized egg of the starfish may be taken as an **ideal cell**. Each prepared slide contains many cells, each perfectly spherical in shape and **without a cell membrane**. Note the **cell-body (cytoplasm)**; the **nucleus**, surrounded by the **nuclear membrane**, and containing the deeply stained, **granular chromatin**; the **nucleolus**, a distinct large body in the nucleus.

Draw one cell, two inches in diameter.

BLOOD

The blood of the vertebrates consists of the liquid **plasma** (not shown in the stained preparations) and at least two

types of cells, the **red and white corpuscles**, which float in the plasma. In permanent stained preparations of the blood, a majority of the corpuscles are usually distorted. Care must be taken to pick out only normal specimens for study. In mounts of fresh blood, when seen by transmitted light, the red corpuscles are yellow and not red.

Blood of a Salamander. Amphibian blood contains the three classes of corpuscles described below:

1. **Red corpuscles**, very large, flat cells, **perfectly elliptical** in face view, long and narrow as seen on edge. In the stained slides, they are all shown in face view and most of them distorted in preparation. Carefully pick out a typical corpuscle and note the features of a typical cell, except that there is no nucleolus. **Draw, 3 inches long, showing cell-body, nucleus, chromatin, nuclear membrane.**

2. **White corpuscles or leucocytes.** They are of several types; considerably smaller than the red, more or less spherical in shape, but in life capable of ameboid movement. Pick out, study, and draw the following: a, **lymphocyte**, small and with a relatively large nucleus; b, large "**mononuclear**," with a single, relatively smaller, nucleus; c, "**polynuclear**," with the nucleus fragmented into three or more parts; d, **eosinophile**, with kidney-shaped nucleus and the cytoplasm filled with pink granules. **Draw the four types, of the same relative size as your drawing of the red corpuscle.**

3. **Spindle cells**, small, purple, spindle-shaped cells. **Draw one.**

Blood of Man.--In human blood there are only the red and white corpuscles. In stained preparations the red corpuscles appear as very small, circular, biconcave, non-nucleated discs. **Draw one, an inch in diameter.** The white corpuscles are of the several types, as in the salamander, but larger than the red corpuscles. **Study and draw the four types as in the salamander.**

Fresh Frog's Blood.—Mount some fresh frog's blood and examine quickly. Note the very numerous **red corpuscles**—their form, structure, etc., as they float in the colorless **plasma**. The nucleus will not show distinctly. **Draw in different positions.** Look for the fewer smaller, **white corpuscles**. Pick out one of the largest irregular ones and study its **ameboid movement**, shown only as a slow change of shape. **Make four or five outline figures at intervals of a minute, as in your study of ameba.** Compare with your figures of ameba.

If time permits, study in the same way fresh human blood (a **very** small drop procured by pricking a finger which has been washed with alcohol, with a heavy needle that has been sterilized by heating in a flame).

EPITHELIAL TISSUES

Pavement Epithelium.—The mesentery of vertebrates is a double layer of peritoneum and is covered on both faces with a single, very thin layer of cells forming a pavement. Study a piece of the mesentery of the cat treated with nitrate of silver, which stains the **cement substance** between the cells; and with paracarmine, which stains the nuclei.

Draw a group of a dozen cells, carefully putting in the details of one or two cells and only the outlines of the remainder. Each cell a half inch in diameter.

Columnar Epithelium.—The intestine of Metazoa generally is lined by a single layer of **columnar cells**, arranged vertical to the surface. This lining in cross-sections of the salamander's intestine is shown as an irregular band. Pick out and study a favorable place where the individual cells are clearly shown. **Draw six or eight, each cell two inches long,** showing the details in only two of the cells.

Columnar Ciliated Epithelium.—Study the cells **in situ** in the inner lining of sections of the intestine of the fresh-water

mussel. These are quite similar in shape to the last type, but each cell has many delicate, filamentous **cilia** extending from its inner, free end into the cavity of the intestine. **Draw a group of six or eight.** Also study carefully the isolated ciliated cells scraped from a frog's mouth. **Draw two or three.**

Stratified Epithelium.—This type is illustrated by the epidermis of all Vertebrates. The mounts are vertical sections of the skin and some of the underlying muscles of the salamander. The epidermis is a dark band on one side of the sections and is composed of several layers of cells.

Carefully make a **large drawing of a small part of the epidermis**, showing the cells about a half inch in diameter.

Squame Cells.—**Very gently** scrape the inside of your cheek (which is lined with stratified epithelium) and mount the flocculent scrapings in a drop of saliva. The superficial cells thus isolated and separated away from the deeper layers of the epithelium are known as **squame cells**.

Draw one or two, two inches in diameter.

Lift the cover-glass and add a small drop of **hemalum stain**; cover and examine after a few minutes. Make note of result. Again lift the cover-glass and treat the same preparation with a small drop of **eosin stain**. Note the result.

Glands of all kinds, in great variety, are modifications of epithelial tissues. One of the larger glands, such as a salivary or a lacrymal (tear) gland, is a great complex of tubes shown mostly cut across in microscopic sections. The prepared slides are of the lacrymal gland of the rabbit. Study a favorable tube, and make a careful large drawing with 2 or 3 cells in detail and the rest in outline.

MUSCULAR TISSUES

Smooth or Involuntary Muscle Fibers.—The simplest of the muscular tissues is the **smooth or involuntary** type, found

especially in the muscular coat of the digestive tract of vertebrates. The specimens in temporary mounts are of the intestine of a frog that has been for a half hour or more in 35 per cent caustic potash solution, which causes the organ to disintegrate into its tissues. The mounts will contain epithelial cells and other tissues as well as the muscle fibers. The details of the nucleus are not shown. Care must be taken not to get the potash on the objective or other objects. Note the very long hair-like, spindle-shaped cells, with the nucleus in the center.

Make four-inch drawing of one fiber.

Cardiac Muscle.—The elements of heart muscle are short cylindrical cells, each with one nucleus; and with the cells arranged end to end into more or less clearly defined columns. The cross striations are but faintly shown. The sections are from the ventricular wall of the rabbit's heart.

Draw a few cells, forming a column.

Striated or Voluntary Muscle Fibers.—The stained preparations of the frog's muscle have been "teased" or frayed out with needles to isolate the very large individual fibers. In favorable isolated fibers, note **cross-striations**; the numerous **nuclei**; the **fibrils**, best seen at the broken ends of the fibers, delicate thread-like filaments into which the substance of the fiber is divided lengthwise.

Draw, an inch or more in diameter, small parts of two fibers which show contrast in sizes.

A small piece of living frog's muscle has been teased out and mounted in salt solution (seven-tenths per cent). At points where the fibers have been torn, look for the very delicate covering sheath, the **sarcolemma**.

Draw accurately parts of two living fibers and label all parts. In one of the figures show the sarcolemma extending between the broken ends of the fiber.

Make an ideal figure of a fiber in transverse section, as you interpret it.



NERVOUS TISSUES

Examine the large isolated stained **nerve cells** from the spinal cord of the ox. These preparations are made by smearing some of the gray matter of the spinal cord of the ox upon the cover glass. They contain other elements besides the large nerve cells. The nerve cells are the largest elements in the preparation, and are easily found with low power. Note cell-body, nucleus, and nucleolus, and the many **dendritic processes**. You may not be able to distinguish the **axis cylinder process** or **axon**. Draw two or three cells of different sizes and types.

Examine cross sections of the spinal cord of a calf or pig embryo in preparations stained with silver. Only a few of the cells are stained, but they are shown in great detail. Note especially the great complexity of the processes of the cells. Note the **inner gray matter** of the cord, indistinctly different from the **outer white matter**. Do not mistake blood vessels for the nerve cells.

Make a large 4-inch general drawing, putting in one or two cells in detail.

CONNECTIVE TISSUES

The so-called **connective tissues** are characterized by the development by the living cells of a great amount of **non-living formed substance** around them, for purposes of support and protection. There are many types, but their general characters may be illustrated by the structure of cartilage and of bone.

Cartilage.—The structure of cartilage may be illustrated by the hyaline type in thin sections from the cartilage at the ends of the long bones. There is a “gristly” **ground substance** or **matrix** formed by the **cartilage cells** and in which they lie imbedded.

Study and draw a small part.

Bone.—Living bone consists of a gristle-like, **organic basis**, permeated by **inorganic calcareous deposits**, which alone remain in dry, bleached bones. Examine a ground section of dry bone and note the concentric ^(lamellae) **lamellæ** around the **Haversian canals**, and including between them the **lacunæ**, which contain the **bone corpuscles** in life. The **canaliculi** connect the lacunæ with each other and with the Haversian canals.

Draw a small portion.

In sections of **decalcified bone**, note the irregular bone corpuscles lying in the lacunæ imbedded in the matrix. **Draw a small part.**

CELL DIVISION—MITOSIS

The tissues of salamander tadpoles are especially favorable objects for the study of the behavior of the chromatin in the **mitotic divisions of cells**. The cells are very large and since the larva grows rapidly, many of the cells show the various stages of **mitosis**, though a majority are always in the **resting condition**. The mounted specimens are strips of epidermis torn from the tail. The epidermis consists of two or three layers of overlapping cells and the thinner parts **near the edge** and tip of the preparation should be picked out for study.

With the low power, find a favorable thin portion of the preparation, and examine with high power. In a typical resting cell, note the various features of cell structure, except that the nucleus is very large and there are two nucleoli.

Draw a resting cell.

Block out spaces for the six figures indicated below and draw them in as you run across the various stages of mitosis in your preparation.

Look for dividing cells. It is easier to begin with a stage in which the two groups of prominent **chromosomes** are diverging from each other (Stage 4), and then to work forwards and backwards through the other stages of division.

Study carefully, noting especially and drawing the following stages: 1, an **early prophase** stage, in which the chromatin has assumed the form of a delicate, long coiled thread, the **spireme**; 2, a **later prophase** stage, in which the spireme has broken up into a definite number of **chromosomes** (28 in this animal) most of them V-shaped; 3, the **metaphase** stage, in which each of the chromosomes is **split lengthwise** into equal halves. 4, a **middle anaphase** stage, in which the two resultant groups of chromosomes are **diverging** from each other; 5, a **late anaphase** or **early telophase** stage, in which the individual chromosomes are losing their identity, and the **cell-body is dividing**; 6, a **late telophase** stage, in which the two **daughter** cells have been formed and the daughter nuclei are becoming **resting nuclei**.

CHAPTER IV

PHYLUM PORIFERA

Leucosolenia sp.

This sponge illustrates the **Ascon type**, the simplest of the sponges. The material for study is from the Massachusetts coast and the mounted specimens are only parts of colonies which branch, twig-like, and contain many individuals. The tip of each twig, containing an osculum, marks, indistinctly, an individual. The body of this sponge is a simple thin-walled tube, with many very minute microscopic inhalent pores, through which water passes to the gastral cavity, to be expelled through the osculum.

Examine the specimen with a hand lens and with the low power, noting the **oscula**; the **individuals**, poorly distinguished from each other. With high power, note the **triradiate spicules** over all the body, except around the osculum, where some of the spicules are needle-like.

Make a simple general outline drawing of the whole specimen and draw the two kinds of spicules.

Grantia sp.

Grantia illustrates the **Sycon type** of sponges. Specimens for study are from the Massachusetts coast.

Examine a specimen in alcohol with hand lens and note **shape**; **body**, with spicules jutting from the surface; **base** for attachment; **osculum** at the free end, surrounded by a funnel of straight spicules; **buds** if any are present.

Draw, x 2 or 3.

Examine the specimens in alcohol, cut into halves lengthwise; also the mounted longitudinal sections. Note **base**;

body-wall; gastral cavity; osculum. In the body-wall note the **flagellated chambers** as diverticula from the central gastral cavity; the **incurrent canals** between them, leading in from the outside.

Make an outline figure, to show only the general features.

Examine mounted transverse sections and study general features as noted above. In a favorable section of one of the flagellated chambers, note the lining **collar cells** of the endoderm; the very flat **dermal layer** (ectoderm) lining the inhalent canal. Try to make out the cells of the jelly between these two. Look for parts of the section showing a flagellated chamber cut tangentially so as to show its wall in face view. Observe the **pores** which lead from the inhalent canals into the flagellated chambers. Study the spicules. Where do you find the tri-radiate and where the straight ones?

Make a large figure of two flagellated chambers and the intervening incurrent canal, putting in the details of one of the chambers.

CHAPTER V

PHYLUM COELENTERATA

THE FRESH-WATER POLYP

Hydra vulgaris and *H. oligactis*

This large and important phylum is represented in fresh water by only a few fresh-water polyps and related forms. The commoner fresh-water polyps in this region are mostly of two species:—1, *Hydra vulgaris*, grayish or brownish, oftener abundant and becoming sexually mature in summer and autumn; 2, *H. oligactis*, grayish, more abundant and becoming sexually mature in colder weather, even in mid-winter in running water. Both of these species are hermaphrodite, but usually the testes (nearer the free end) are matured before the ovaries (nearer the middle of the body). A green hydra, *Hydra viridissima*, is sometimes found abundantly.

General Structure.—With hand lens and low power, examine a specimen that has been quiet for some time in a dish of hydrant water, noting its activities. Note the long cylindrical **body**, attached by its **foot** and bearing near its free end a circle of **tentacles** (how many?); within the circle of tentacles, the conical free end of the body, the **hypostome**; in its center, the **mouth**, usually closed and difficult to observe; the numerous small swellings on the body, but especially on the tentacles, due to groups of **nettle cells (nematocysts)**. Are there any **buds** on the sides of your specimen? If so, in what stages of development? Any **spermaries** (conical swellings nearer the free end) or **ovaries** (rounded swellings nearer the middle)?

Touch one of the tentacles and prod the body of the animal. What physiological properties are involved in the resultant reactions?

If you have time, touch a very small piece of meat or a water flea to one of the tentacles of a well-expanded specimen and observe the **ingestion** of the food particle.

Make an accurate 5-inch drawing of a living specimen in the extended condition and an outline drawing of a contracted specimen.

Study a mounted living specimen with high power. Examine the swellings on the tentacles, referring to the accompanying figures. Observe the **nematocyst** within a nettle cell or **cnidoblast** and the trigger or **cnidocil** projecting from the latter. Tap sharply on the cover-glass with a pencil point. This acts as an **irritant** and causes the **discharge of the filament** from the nematocyst and, frequently, the extrusion of the whole nematocyst from the cnidoblast as in Fig. 3B.

Study carefully and draw one of the nematocysts which has discharged its filament.

Histology of Hydra. General Statement.—In transverse sections of a hydra you should get a sharp idea of the **fundamental plan of structure** in the Coelenterata as composed of **two clear-cut layers of cells** (ectoderm and endoderm); a **non-cellular layer of supporting substance** between (mesoglea, in this case very thin and **secreted by the ectoderm**); also of the presence of a **single cavity** within (the **gastrovascular or digestive cavity**) and the **absence of a true celom or body-cavity**.

In the ectoderm note the various kinds of cells:—the large supporting or **epitheliomuscular cells**, occupying most of this layer; the **cnidoblasts** or stinging cells, each with a

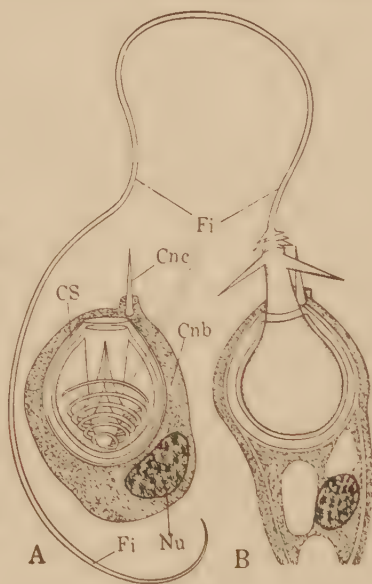


Fig. 3. A.—Cnidoblast cell from Hydra containing an undischarged nematocyst. (After Schneider.)

B.—Same as A, with the nematocyst discharged.

Cnb, cnidoblast; Cnc, cnidocil; CS, contractile sheath; Fi, filament; Nu, nucleus.

nematocyst; the small **interstitial** cells among the bases of the supporting cells. Look for small dot-like structures on the outer side of the mesoglea, the **muscle processes** of the ectoderm cells cut across. Note the large, **vacuolated endoderm cells**, with their free ends **granular**.

Make a six-inch outline figure of the whole section and put in accurately the details of a small sector of the body-wall.

Series of the longitudinal sections should also be examined. Each slide contains a small hydra cut into a **series** of sections, and all **mounted in order**. As it is only the exceptional specimen that is killed straight, you should get a knowledge of different parts from different sections. For instance, one section may show favorably the mouth and hypostome; another the foot, etc.

Make a large semi-diagrammatic figure of a longitudinal section to show your interpretation of the structure as derived from the study of the series.

GENERAL STATEMENT FOR THE HYDROZOA

The Hydrozoa include only a very few fresh-water representatives (hydra and a half dozen others), but a great many marine forms of extremely diverse form and appearance. They are, however, all reducible to the same fundamental plan of structure as typified by the fresh-water hydra.

A majority of the marine Hydrozoa develop into **colonies of hydra-like individuals**, called **hydranths** or **polyps**. In these colonial forms the fertilized egg develops directly into a single hydra-like hydranth. This parent hydranth forms buds, as in Hydra; but, instead of separating from the parent hydranth to become independent, as in Hydra, they all remain together. By this process of budding or **asexual reproduction** there is thus formed a **hydroid colony**, sometimes composed of thousands of hydranths.

In some hydroids the colony branches, tree-like, as in Pennaria and Obelia. In others (Podocoryne, Hydractina)

the colony is sessile. In these last the first hydranth buds at its base in the form of root-like tubes which, spreading over the surface on which the colony is growing, bud out new hydranths and form a sessile, unbranched colony.

Eventually, in the typical hydroid colony, some of the buds, instead of becoming typical hydranths, develop into medusæ or jellyfish which are destined to break loose, swim away, and lead an independent existence. They feed, grow, and produce reproductive cells. These are extruded into the water, where the eggs are fertilized, develop, and complete thus the life-cycle. All of the medusæ budded off from any one colony are either male or female.

The life-cycle may be summarized as follows: the fertilized egg in its embryonic development gives rise to a single hydranth; this hydranth reproduces asexually, by repeated budding, and gives rise to the colony; some of the asexually produced buds become sexual medusæ, which produce the germ cells, male or female as the case may be. The alternating of asexual and sexual stages in the same life-cycle is called "alternation of generations."

In some forms of hydroids the medusæ are very small when liberated from the parent colony and are destined to grow greatly before the reproductive cells are matured (in *Bougainvillea*, *Podocoryne*, *Obelia*); in others the medusæ are small, but fully developed, when liberated, lack a mouth, never feed or grow while free-swimming, and swim about only a few hours—only long enough to distribute the reproductive cells (*Pennaria*); in others still the medusæ have degenerated still more into simple reproductive organs on the body of the parent hydranth (*Hydractinia*).

BRANCHING TUBULARIAN HYDROIDS

Pennaria sp. and *Bougainvillea* sp.

Pennaria is a colonial form of tubularian hydroid. The

individual which develops from the egg is very similar to a hydra. By repeated budding (asexual reproduction), there arises the whole branching **colony**, oftentimes composed of thousands of hydra-like individuals (the **hydranths** or **polyps**). In the fully developed colony most of the buds develop into free-swimming medusæ. The medusæ of *Bougainvillea* are of essentially the same organization as *Gonionemus*, the next form to be studied.

Examine the unstained sprigs of pennaria in the dishes, noting the form of the colony, hydranths and medusa buds.

Draw a sprig of a dozen individuals, x 6, and a 2-inch figure of a surface view of one hydranth with medusa buds.

In the stained slides of *bougainvillea*, note the hydra-like individuals, and, besides, **buds** in various stages of development into hydranths and into medusæ, the medusa buds being more or less spherical, smaller, and more deeply stained than the hydranth buds. Examine a small hydranth with the high power and compare it with hydra. Study a clear portion of the stem, noting the outer tough protective covering, the **perisarc**; within it the ectoderm, mesoglea, endoderm, and digestive cavity. Note that all of these features are continuous through the colony.

Draw a large figure of a surface view of one individual, and an ideal longitudinal section of a hydranth as you interpret it.

A MEDUSA OR JELLY FISH

Gonionemus murbachii

Gonionemus is one of the Hydromedusæ, although the hydroid stage in its life-history is considerably modified and indistinct. However, in its developed condition the medusa is typical and illustrates very beautifully the general characters of the medusa stage, or sexual generation, of the Hydrozoa.



Observe the umbrella-like form; the **exumbrella** (convex outer surface) and the **sub-umbrella** (concave inner surface); the **manubrium**, hanging into the cavity of the sub-umbrella, and with the **mouth** in its center. Note the **tentacles** at the margin of the bell—their number and nature; the **eye-spots** at the bases of the tentacles; the **velum**, a thin shelf extending inwards from near the margin of the sub-umbrella. The manubrium contains the **stomach**; from it four **radial canals** radiate outwards and unite with the **circular canal** which runs around the edge of the bell. On the sub-umbrellar side of the radial canals, note the corrugated **reproductive organs**, either male or female.

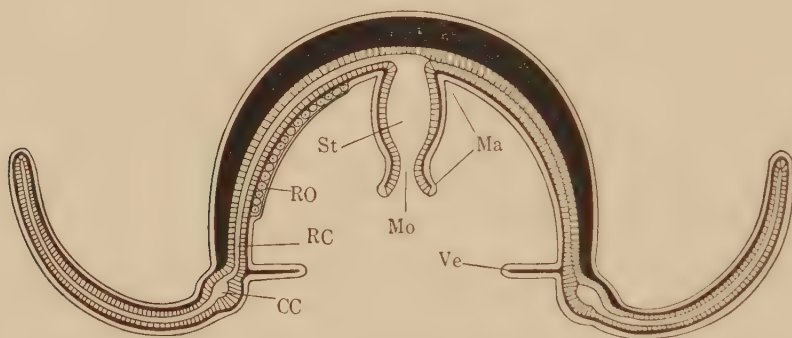


Fig. 4—An imaginary vertical section of a medusa passing through a radial canal of the left side of the figure and slightly to one side of that of the right side. The ectoderm throughout is represented as a white layer, the endoderm as striated and the mesoglea as black. In the diagram the ectoderm and endoderm are of greater thickness relative to the mesoglea than is actually the case, and the tentacles too short.

CC, circular canal; **Ma**, manubrium; **Mo**, mouth; **RC**, radial canal; **RO**, reproductive organ, in this case the ovary containing eggs; **St**, stomach; **Ve**, velum.

Draw an oblique view, 4 or 5 inches in diameter. Also, make a diagram of an imaginary vertical section passing through a radial canal on one side and between two canals on the opposite side. Represent ectoderm, endoderm and mesoglea diagrammatically.

A CAMPANULARIAN HYDROID

Obelia sp.

The general form of the colony is the same as in *Pennaria* and *Bougainvillea*, but there are essential differences in both nutritive and reproductive individuals (the latter called **blastostyles**) and also in the medusæ budded off from the blastostyles. The nutritive hydranths have the perisarc extending around them as cups or **thecæ**. The blastostyles are formed by budding and from each blastostyle arise, as buds, a dozen or more small medusæ, of the leptomedusa type (with otolithic vesicles, and with reproductive organs on the radial canals).

Study the various features described above that are to be made out in your specimen. **Make a general sketch of a small branch of a dozen hydranths.** Also a figure of a longitudinal section of a well-expanded nutritive hydranth as you interpret its structure by examination with high power.

SEA-ANEMONES

Metridium sp. and *Sagartia* sp.

Preserved specimens of sea-anemones are always contracted more or less. The large specimens are of *Metridium* and are to be used for the gross structure. *Sagartia* is a small form. The larger microscopic stained sections in the mounted slides are of sexually mature, adult individuals.

In a whole specimen, note the cylindrical **column**, with **base** for attachment at one end and the **circumoral disc** at the other; the **mouth** in the center of the disc; the very numerous **tentacles**, simple diverticula of the body wall. Do the tentacles seem to have any definite size, number or arrangement?

Draw your animal from oblique view, x 1.

Study a specimen divided into halves from disc to base. Do not further dissect or injure the specimen. Note the **esophagus**, leading from the mouth into the **digestive chamber**; the **mesenteries**, septa extending from the body-wall into the digestive cavity. Six pairs, the **primary mesenteries**, extend to and unite with the wall of the esophagus. The **secondary**, **tertiary**, and smaller septa are of decreasing size. Note the **mesenteric pore**, a hole in each primary mesentery near the disc; the **mesenteric filaments**, wavy, thickened edges of the mesenteries below the esophagus; the **reproductive organs**, wavy thickenings along the mesenteries near their edges; the coiled **acontia**, filaments arising from the edges of the mesenteries near their base and in life capable of being extruded for defense through pores in the body-wall.

Draw your specimen.

Sections of Sagartia.—Each slide contains sections through the esophagus and below it, of individuals of three different sizes. Some of the slides contain an additional section of a sexually mature male individual to show the reproductive organs. Simple, outline figures are to be made of the sections as directed, except that a sector of the middle-sized specimen is to be drawn large, in detail.

1.—In some sections of the small sagartia, not all of the six pairs of primary mesenteries are established. In the section through the level of the esophagus, note **body-wall** and **esophagus**, both composed of **ectoderm**, **mesoglea** and **endoderm**; the mesenteries, some of them through the mesenteric pores; the **longitudinal muscles**.

Draw a simple outline figure of the section through the esophagus, and one below it.

2.—In the middle-sized sagartia, in a section passing through the esophagus, note the six pairs of primary mesenteries reaching to the esophagus, and the secondary and tertiary between the pairs of primary mesenteries. Two pairs

of primary mesenteries at the angles of the esophagus, with their longitudinal muscles turned away from each other, are called the **directive septa**. A plane passing between them divides the animal into **symmetrical halves**.

Make a simple outline figure to show what you have found in this section; also a large figure of a sector, representing **ectoderm**, **endoderm**, and **mesoglea** diagrammatically.

Study and make a simple outline figure of the section below the esophagus, noting, in addition to other features, the **mesenteric filaments**.

3.—Study the two sections of the larger specimen in the same way and make outline figures. In the section of the sexually mature specimen, note the **reproductive organs** in the mesenteries, composed of very **small spermatozoa** in the male and of **large ova** in the female.

CHAPTER VI

PHYLUM PLATYHELMINTHES

PLANARIA Sp.

Species of *Planaria* are fresh-water forms found in quiet places in lakes and streams. They lead a secluded life under stones and vegetation, and avoid strong light. The stained, mounted specimens were fed with India ink to demonstrate more clearly the rather complicated branched intestine.

Structure.—Upon living and mounted specimens note **form; head and body; auricles**, projections at the sides of the head; **eyes; mouth, pharynx, intestine**.

Draw, dorsal view, 3 inches long.

Behavior.—Behavior experiments require much care and, so far as possible, should be repeated on more than one animal. Follow the directions below, and keep carefully written notes of all results.

1. **Locomotion.**—Note the normal **gliding motion** by action of the cilia; the position of the tip of the head and auricles in side view (explain); its muscular **crawling** (at which end does the wave of contraction begin?) Can the worm glide or crawl along the surface of the water? Outside the water?

2. **Righting reaction.**—Carefully turn a specimen over on its back and note its behavior.

3. **Reaction to light.**—Use sunlight or strong electric light from one side, and determine whether *Planaria* goes towards or away from the light. Repeat several times if necessary to reach a definite decision.

4. **Reaction to mechanical stimuli.**—a, while the worm is gliding smoothly along the bottom of the dish, **jar the dish**, and note the response. Determine the least disturbance that will cause a response. b, while the worm is gliding along, **gently touch the tip of the tail** with a bristle. Compare the response with that given in "a." c, in the same way, **touch an auricle**. Compare with "a" and "b."

5. **Reactions to a current of water (by demonstration).** Make note of the results.

6. **Feeding reactions.**—Shade the dish from strong light and leave the worm undisturbed for several minutes. Then very gently drop a small piece of blood clot into the center of the dish. a, observe very carefully and note the first evidence that the worm receives a stimulus from the food. How do you explain the first actions? b, make a quick sketch of the dish, food, and the path which the worm pursues in finding the food. Does it pursue the shortest possible path? Explain. How long for the worm to find the food? c, note very closely what the worm does when it reaches the food; the position of the head and auricles. When the intestine becomes filled with dark blood, quickly turn the worm over to see the extruded pharynx. Now observe the branches of the intestine, and draw them into the large general figure, made above, so far as not already done.

Regeneration.—Many studies on regeneration have been made in recent years and Planaria has been one of the favorite objects for study.

Carefully follow out the following: a, while the worm is gliding across the bottom of the dish, cut it in two with a sharp knife, just back of the pharynx (or alternate students just back of the pharynx and just in front of it). How much evidence do you see that the worm suffered pain? Compare the reactions with those with other stimuli, noted above. b, plan for a series of four or five pairs of figures to show the process of regeneration of anterior and posterior halves, on

succeeding days. Now draw the first figures, an inch and a half long, showing the two halves of the worm just after the operation. Across your large figure, above, draw a dotted line to show the position of the cut. c, place your specimen in the bottle designated, and keep till later laboratory periods. Then complete the series of figures, drawn in the same position and proportions, and showing accurately the shape and development of the regenerated part of each half.

MISCELLANEOUS FLATWORMS

1. **Microstomum**, a very simple, microscopic, free-swimming, fresh-water turbellarian. It swims very actively by means of the cilia which cover the whole surface of the body. In the stained mounted specimens note: **form of body**; **body-wall**; **digestive tract**, with **mouth**, **pharynx**, and very simple finger-shaped **intestine**. **Reproduction** is almost always by **fission**, an animal constricting into two or more individuals. **Draw, showing these features.**

2. **The liver fluke of the sheep** (*Fasciola hepatica*). **Draw**, showing shape, mouth, posterior sucker, and as much of the digestive and reproductive systems as you can and have time for.

3. A **tapeworm** from the intestine of the "spoonbill" fish. In the mounted slides, study and **draw**, showing **head** with a single large **ventral sucker**; the **segments** or **proglottides** back of the head, of increasing size and development. In the oldest segments, make out all of the reproductive systems you can and have time for, using figures of the human tapeworm to help you.

4. A **human tapeworm** (*Tænia solium*). In the excellent demonstration specimen from the intestine of man, note and draw the very small **scolex** or "head," and the segments from representative regions, showing increasing development.

CHAPTER VII

PHYLUM NEMATHELMINTHES

THE VINEGAR EEL

Anguillula aceti

This nematode grows abundantly in fermented fruit juices, especially upon the "mother" of vinegar. The eggs are fertilized and develop in the body of the mother worm, and the young worms are born alive in the adult form. The living mounts contain specimens of both sexes and of all sizes, from those just born to the full-grown worms. The largest specimens, about 1-12 inch long, are females. The full-grown males are about 1-16 inch long, and are distinguished from the females by a pair of long chitinous rods just inside the anal opening.

Pick out a specimen of medium size (male or young female) which is held quietly between the slide and cover-glass. Nearly all of the specimens will be shown in lateral view. Note: blunt **anterior end**, with the **mouth** at its tip; very pointed **posterior end**; **anus**, a short distance from the posterior end; straight **digestive tube**, consisting of **esophagus** with "bulb," and long **intestine**; **body-wall**; **body-cavity**.

Draw a large, page-length figure to show all you have made out of the general anatomy.

Select a large female for the study of the female reproductive system and the development of the eggs. Near the middle of the worm, on the mid-ventral line, is the **genital pore**, which serves both for receiving sperm cells from the male and for the birth of the young worms. From the pore a single tube extends forward, with the larger part serving as a **uterus** for the development of the embryos. The anterior

part of the tube is bent backward and serves as an **ovary** for the formation of the ova. The uterus may contain eggs in all stages of development from the fertilized egg and early cleavage stages, to the fully developed, coiled-up embryos, ready to be born. So far as necessary, examine several adults and try to make out a fairly complete series of developmental stages.

Make a 5-inch drawing of the reproductive system and embryology, combining the results of your study.

In the male, a single **genital tube** lies ventral to the posterior end of the intestine and empties into it near the anus. The anterior end of the tube serves as a **testis** and its cells are obscure; in the middle part the cells are more clearly shown. In the posterior end, the small spherical **sperm cells** may be seen in the tube. Observe the **spicules** ("**penial setae**") in specimens treated with strong formalin, which causes them to project to the outside.

Make a 3-inch figure of the posterior end of the intestine and the genital tube to show these features.

MISCELLANEOUS ROUNDWORMS

1. **Ascaris lumbricoides**, the roundworm parasite from the intestine of children and pigs. Draw, natural size, showing shape, mouth, anus.

2. **Trichinella**, in sections of muscle of rat or man. *Trichinella*, in the fully developed condition, is a microscopic form, living coiled up and encysted among the voluntary muscle fibers of man, pig, and rat. The slides contain longitudinal sections of muscle of rat or man, containing the specimens of coiled, encysted *Trichinella*. Make a quick drawing, showing the coiled parasites among the muscle fibers.

CHAPTER VIII

PHYLUM ANNELIDA

THE SANDWORM *124 segments*

Nereis virens

This species usually lives in more or less coarse, loose sand, between tides, along the Atlantic coast. In life the pharynx is capable of being everted or rolled out. This is shown in the preserved specimens, with the pair of heavy chitinous teeth at the sides.

External Anatomy.—Observe, as external features, the first or **peristomial segment** around the mouth, modified into the **head**; on it, the projecting triangular **prostomium**; the **palps** at the sides of the prostomium; a pair of small **tentacles** arising from the prostomium and four pairs from the peristomium; two pairs of **eyes**. Note the rest of the animal made up of **segments** or **somites** of uniform character (count and make a note of the number) each bearing a pair of **parapodia**; the posterior segment, possessing a pair of long **feelers** or **cirri** instead of parapodia; the anus, in the posterior segment.

Draw a dorsal view of the anterior six and posterior three somites, $\times 2$, *times 3*.

In this and in all segmented animals which you study hereafter, number the segments in your drawings, always beginning at the anterior end.

THE EARTHWORM

Lumbricus terrestris and *Allobophora* sp.

The very large specimens, for the study of the anatomy of the earthworm, belong to the species *L. terrestris*, found

abundantly in soddy places in the East and South; only locally in Minnesota. The smaller specimens used for the study of the living animal belong to one or more of our local forms, species of *Allobophora*. Each animal produces both male and female sexual cells—is hermaphrodite.

External Characters.—Examine these in a preserved specimen, moistened from time to time to prevent drying. The body is made up of **segments**; count them and make note of the number. Are the **anterior** and **posterior** ends alike? The **ventral** and **dorsal** sides? Are all the segments alike? Which ones enter into the formation of the swollen **clitellum**?

Note the following **external openings**: the **mouth**, in the first segment, under the **prostomium**; the **anus** in the last segment; a pair of **male reproductive openings** on the ventral side of the 15th segment; the **dorsal pores**, one leading from the anterior end of each segment to the exterior, on the mid-dorsal line (seen easily if the specimen be sharply bent ventrally). The following openings on the ventral side are difficult to observe, and you should use the accompanying diagram (Fig. 5) showing these structures to help you locate them:—the **female openings**, a pair of small pores of the oviducts on the ventral side of the 14th segment; the openings of the **seminal receptacles**, two pairs of small pores on the sides between the 9th and 10th, and 10th and 11th segments; the openings of the **nephridia**, a pair of pores on each segment except the first three and the last.

The **setæ** are small bristle-like structures, four pairs in each segment, two pairs on the ventral surface and two at the sides. Pass the finger both ways along the sides of the body of the worm to determine the direction in which they project. Are there any **eyes** or other **organs of special sense**? Any **parapodia** or other prominent structures of offense or defense? Can you account for what you find from the animal's mode of life?

Draw a ventral view of the anterior forty and posterior five segments, x 2 or 3, numbering every fifth segment, beginning at the anterior end.

The Living Animal.—In all of the observations and experiments on the living worm, keep accurate notes of all you find. Carefully study the **locomotion** of the living animal, observing and making note of the sequence of events that take place. Note the **pulsation (peristaltic contraction)** of the **dorsal blood-vessel**. Make note of the direction of the blood-flow and frequency per minute.

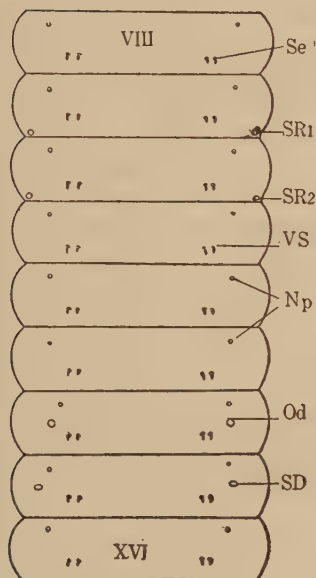


Fig. 5.—Diagram, ventral view, of the 8th to 16th segments of the earthworm to show the external reproductive and nephridial openings.

Np, openings of nephridia, a pair on each segment; **Od**, openings of oviducts; **SD**, openings of sperm ducts; **Se**, ventral setae; **SR1**, and **SR2**, openings of first and second pairs of seminal receptacles; **VIII-XVI**, 8th and 16th segments.

Effect of Changes of Temperature.—Place a specimen in **cold water** (near the freezing point). What immediate results? Observe for a few minutes and note the effect, both upon the general activities and upon the rate of pulsation of the dorsal blood-vessel. In the same way, place another specimen in **warm water** (about 40 degrees C.) Observe and note the results, both immediate and after a few minutes. Compare with the results you secured with *Paramecium*.

Application of Stimuli.—The earthworm offers very excellent material for the application of all of the four fundamental types of stimuli that affect ani-

mal life. The experiments indicated below should be repeated on two or more worms, to insure that the reactions are normal. Great care must be taken with the animals to see that other stimuli are not applied at the same time, so as to confuse the results. Carefully follow out the following experiments and make careful notes of your results.

1. **Mechanically stimulate** a quiet specimen by prodding or slightly pinching it at the anterior end; at the posterior end. Note the results.

Let a specimen crawl freely over the bottom of a paraffined pan. With a sharp scalpel cut it into halves by a quick chop. This acts as a mechanical stimulus upon both ends, traveling forwards over the anterior half, and backwards over the posterior half. Observe carefully and make note of the results, and compare with the results of the mechanical stimuli upon the whole worm. Observe the halves for a minute or two. After the halves have recovered from the immediate shock, perform the same cutting experiment upon each half as it crawls along. Repeat till you get uniform results. Perform the same experiments upon the quarter worms.

Remembering that the most centralized part of the nervous system is in the extreme anterior part of the animal, do your experiments offer any evidence as to whether it suffers pain under the cutting experiments?

2. **Chemically stimulate** the anterior end by placing upon it a small square of filter paper saturated with 4 per cent solution of acetic acid. Note the result. Wash the worm, or better, place it back in water and take another worm. In the same way, apply the stimulus to the posterior end. Also to the middle. Compare with the results with mechanical stimuli.

3. **Thermally stimulate** a worm by dropping upon the anterior end a drop of hot water. Note the result. Let the

worm rest a moment and, in the same way, apply a drop to the posterior end. Upon another worm, apply a drop to the middle.

4. **Electrically stimulate** a worm by touching the electrodes of an electric circuit to the anterior end, and make or break the circuit. Note the results. In the same way, apply to the posterior end, and to the middle of the worm. Results?

What are your conclusions and generalizations as to the results with the application of all of the four types of stimuli?

Internal Anatomy.—In all dissections you must be especially careful not to injure essential parts, and not to remove any parts or organs unless directed to do so. Refer constantly to figs. 6, 7 and 8 during the dissection of the earth-worm.

Pin your alcoholic specimen down in water, **dorsal side up**, by means of pins through prostomium and the posterior end. With small scissors make a **median incision** forward through the body-wall (only) from the **40th** to the 1st segment. Very carefully separate the sides of the body-wall from the internal structures of the anterior forty segments, noting, as you proceed, the spacious **body-cavity**, between the body-wall and digestive tract. It is divided into ~~com-~~partments (how many?) by **septa** which stretch from the body-wall to the digestive tract. Pin out on both sides, inserting pins obliquely outward in the **10th, 12th and 15th segments for landmarks**, and wherever else needed. Expose the small yellowish, bi-lobed **brain** in the third segment. In about segments 9-14, the large white seminal vesicles arch dorsally over the median organs. They should be very carefully loosened from the parts below, and pinned out at the sides, as shown in fig. 8.

Note, as parts of the body-wall, the very thin iridescent **cuticle**; the thin **epidermal layer**; the **muscular layer**, con-

LABORATORY DIRECTIONS

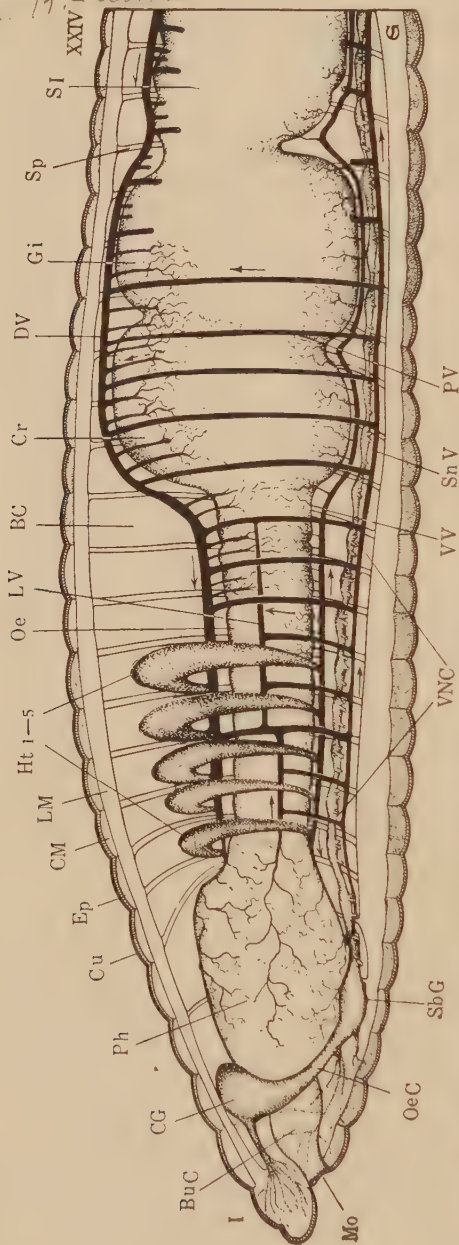


Fig. 6.—A somewhat diagrammatic dissection of the anterior end of the earthworm, from the left side. The body-wall is removed to the mid-line dorsally and ventrally. The nephridia and the reproductive systems are not represented. The arrows indicate the direction of the blood-flow in the various blood vessels.

BC, body-cavity; BuC, buccal or mouth capacity; CG, cerebral ganglia, brain or supra-esophageal ganglia; CM, circular muscles; Cr, crop; Cu, cuticle; DV, dorsal blood-vessel; Ep, outer epithelium (epidermis); Gi, gizzard; Ht 1-5, hearts; LV, lateral vessel; LM, longitudinal muscles; Mo, mouth; Oe, esophagus; OeC, esophageal connective; PV, parietal vessels; Ph, pharynx; SI, intestine; Sp, one of the septa; SnV, subneural blood-vessel; SbG, sub-esophageal ganglion or first ganglion of the ventral nerve-cord; VNC, ventral nerve-cord; VV, ventral blood-vessel; I-XXIV, 1st to 24th segments.



sisting of an outer **circular** layer interrupted at the septa, and the thicker **longitudinal** layer, divided into bands; the **peritoneum**, the membrane lining the body-cavity and covering the various organs in it. *omit.*

Study the **digestive tract**, observing the following regions:—a short **mouth cavity**; the longer, thick-walled **pharynx** through about four segments, with muscles radiating from it to the body-wall; the narrow esophagus (to be seen more clearly later on), through about six segments; the short, enlarged **crop**; the thick walled **gizzard**. From the gizzard the **intestine** stretches to the anus, as a long, unspecialized tube. Separate the body-wall from the intestine sufficiently at several points posterior to the 40th segment to observe the character of the intestine.

Observe, as parts of the **reproductive system**, at the sides of the digestive tract, the **seminal receptacles**, two pairs of white small spherical sacs lying in the 9th and 10th segments; the **seminal vesicles**, three pairs of larger vesicles at the sides of the esophagus. Note, on the dorsal side of the digestive tract, the **dorsal blood-vessel** and, arising from it, several pairs of transverse vessels in each segment. One pair of these in each of the 7th to 11th segments inclusive are specialized as the “**hearts**” which, in life, are especially pulsatile and assist in propelling the blood in its circulation from the dorsal to the ventral side.

Draw the anterior 25 segments from the dorsal side, x 4, showing the features you have studied, but not representing the details of the body-wall. Number every fifth segment V, X, XV, etc.

The **Excretory Organs**.—These are the **nephridia**, a pair of intricate coiled tubes in each segment except the first three and the last one.

They may be studied in one of the anterior segments. Referring to fig. 7, study one in detail, noting its **internal end** (the funnel-shaped **nephrostome**) penetrating through the septum at the anterior end of the segment in which it lies and leading from the segment in front; the long coiled tube, consisting of a longer narrow, and a shorter wide portion; the **external opening** (the **nephridiopore**).

Draw a pair of nephridia as seen in dorsal view, x8.

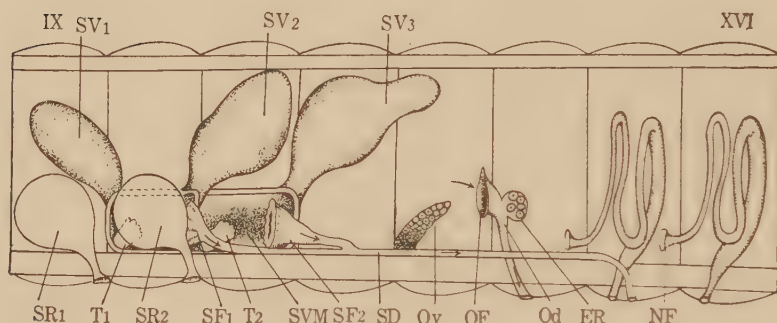


Fig. 7.—Diagram of the reproductive and excretory systems of the earthworm, right lateral view. The three seminal vesicles of the right side are represented as removed and the median seminal vesicles as opened from the right side, so as to show the testes within and the seminal funnels leading from the median pouches into the seminal ducts. The nephridia of only the 15th and 16th segments are represented.

IX-XVI, ninth to sixteenth segments; **ER**, egg receptacle, with eggs, as a diverticulum upon the oviduct; **NF**, nephridial funnel; **Od**, oviduct beginning in a wide funnel in the posterior wall of the 13th segment and opening on the 14th segment; **OF**, funnel-shaped mouth of the oviduct; **Ov**, ovary; **SD**, sperm duct formed by the union of two ducts from the median seminal vesicles of the 10th and 11th segments; **SF1** and **SF2**, the sperm funnels in the 10th and 11th segments; **SR1** and **SR2**, seminal receptacles in the 9th and 10th segments; **SV1**, **SV2**, **SV3** first, second and third lateral seminal vesicles of the left side; **SVM**, second median seminal vesicle; **T1** and **T2**, first and second testes, enclosed within the median seminal vesicles of the 10th and 11th segments.

The Reproductive Systems.—Lay open your specimen as before and pin out the body-wall on both sides with pins obliquely outwards in the 10th, 12th, and 15th segments for

landmarks, and wherever else needed. Cut across the digestive tract just posterior to the gizzard and very **carefully free it forward to the fourth segment**, along with the blood-vessels, noting as you proceed the **ventral vessel** under the intestine.

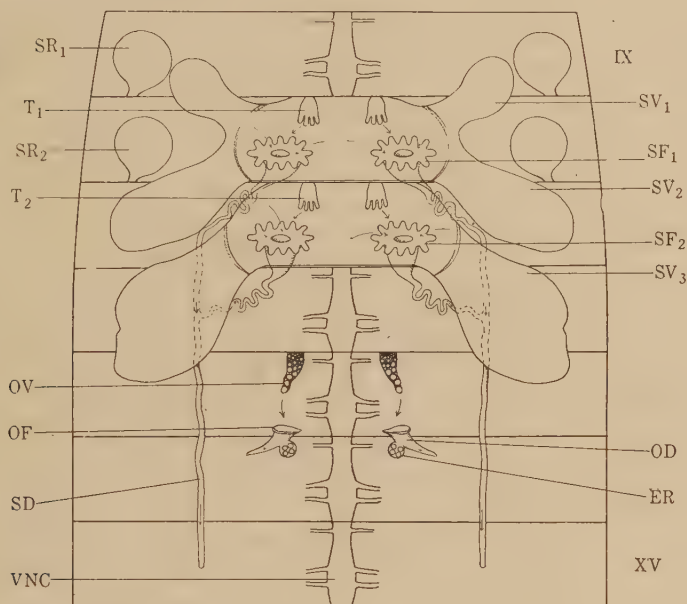


Fig. 8.—Diagram of the reproductive systems of the earthworm, dorsal view. The median seminal vesicles are represented as dissected open so as to expose the testes and seminal funnels; the lateral seminal vesicles as flattened out ventrally. (Fig. 8 drawn by Helen Sanborn.)

ER, egg receptacle; OD, oviduct; OF, funnel of oviduct; OV, ovary; SD, sperm duct; SF1 and SF2, first and second seminal funnels; SR1, SR2, first and second pairs of seminal receptacles; SV1, SV2, SV3, first, second, and third lateral seminal vesicles; T1, T2, first and second pairs of testes; VNC, ventral nerve cord with three pairs of lateral nerves in each segment; IX, XV, 9th and 15th segments.

Pin out the digestive tract obliquely backwards to your left. Very carefully dissect away the seminal vesicles of the left side and cut open the median seminal pouches to expose the left **testes**, one each at the anterior ends of the 10th and 11th segments near the mid-ventral line. Just posterior to the

testes on each side lie the two funnel-shaped openings into the two **seminal ducts**, which unite in the 12th segment to form the single duct which opens to the exterior upon the 15th segment.

Very carefully clear away the nephridia of the 13th segment. Look for the pair of **ovaries**, very small conical structures a millimetre in length, lying against the septum at the anterior end of the 13th segment, very near to the nerve-cord which is on the mid-line. The **oviducts** are a pair of small, narrow funnel-shaped tubes just posterior to the ovaries. Their internal funnel-shaped openings are in the posterior septum of the 13th segment. The ducts penetrate the septum into the 14th segment and lead obliquely outward, to open to the exterior. On the wall of each oviduct is an out-pouching (the **egg receptacle**) for the storage of eggs.

Insert an insect pin in the 13th segment directly between the ovary and oviduct, and another at the junction of the two branches of the sperm duct in the 12th segment, to demonstrate these features.

Draw all that you have made out of the reproductive systems, x 4.

The Nervous System.—The **ventral nerve-cord** extends throughout the length of the animal posterior to the fourth segment and undergoes no specialization in the various regions. It, as well as the brain, has already been exposed in the anterior part of the body in your previous dissections. If the ventral nerve cord is not already exposed, very carefully remove the esophagus and pharynx forward to the 4 segment. Remove also all of the seminal vesicles to expose the ventral nerve cord. Study its character in the anterior ten or fifteen segments noting, in each segment, an enlargement or **ganglion**, and **three pairs of nerves**, two from the ganglion and a third pair from the cord anterior to the ganglion. Trace the cord forwards noting, in the 3 segment, that

it divides and the two halves diverge to pass around the digestive tract on either side as the **esophageal connectives**, which unite dorsally with the **supra-esophageal ganglia** or **brain**. There is thus formed a complete **nerve-ring**. Observe the small nerves running forwards from the brain and connectives to supply the anterior parts.

Draw a dorsal view of the nervous system (only) of the first eight or ten segments, showing all you have made out, x 12.

Study of Transverse Sections—Histology.—The transverse sections of the earthworm, prepared to illustrate the histology, form **series mounted in order**. Each slide contains at least one segment cut into thicker sections to show the more general features; and, in addition, a row of thinner sections for the details of histology. In these sections you should get a clear idea of a **celomate** animal, with the **body-wall** as a tube on the outside; the **digestive tract** as a tube inside; the **celom** or **body-cavity** between the two. For the histology, look over the thin sections very carefully and study the parts which show best.

In a typical section, seek carefully for the best places, and note the following features of the body-wall from without inwards:—the very thin **cuticle**; the **epidermis**, consisting of a single layer of cells, including many swollen **gland cells**; the two **muscular layers**, consisting of a thinner outer layer of **circular muscle fibers** and an **inner longitudinal layer** divided into several bands; the **peritoneum**, a thin layer of flat cells lining the body cavity. Sections of the intestine include the same layers of cells as the body-wall, but in reverse order, and with the layers very differently stressed. The layers in order, starting from the outside, are:—**peritoneum**, greatly thickened, with its cells forming the elongated **yellow cells**, which are especially developed in the **typhlosole**, a longitudinal indentation on the dorsal side of the intestine; the **longi-**

tudinal muscles, composed of only separate fibers lying among the bases of the yellow cells; the **circular muscles**, forming a thin layer; the **epithelial layer**, consisting of a single layer of elongated ciliated cells, lining the intestinal cavity. Note the **dorsal**, **ventral**, and **sub-neural** blood vessels. Pick out and study sections showing the **setæ** lying in in-pouchings of the epidermis. In a section of the **nerve-cord** through a **ganglion**, note the large **nerve cells**, on the ventral side; the numerous small **nerve fibers** forming a network, and a few large **giant fibers**, on the dorsal side.

Make a large 5-inch general figure of a transverse section, combining the features made out in your study, but not putting in the cell structures; and separate large figures to show the detailed structure of the body-wall, intestinal wall and nerve-cord.

Examine the prepared slides of the **ovary**, noting the very small **ova** in the base of the ovary, and the larger ones of increasing size near the free end, each one with the features studied in the immature eggs of the star fish.

Make a 2-inch general drawing of the whole ovary, and a separate large, 2-inch drawing of one of the largest ova.

CHAPTER IX

PHYLUM ARTHROPODA

THE FRESH-WATER CRAYFISH AND THE LOBSTER

Cambarus sp. and *Homarus americanus*

Various species of fresh-water crayfish are found in ponds, lakes and streams in most parts of the world where the water contains sufficient amounts of lime salts in solution to harden the exoskeleton. Several species are abundant in the streams and lakes of Minnesota. The specimens of the lobster are from our rocky North Atlantic coast. These two forms are interchangeable for study, differing from each other only in minor details.

So far as living specimens of crayfish in the aquaria are available, they should be observed for many features, especially for living activities. Note color of various parts of the animal; motions of the two pairs of antennae; position of the various walking legs, both at rest and during locomotion; position of the posterior end of the abdomen at different times; use of the abdomen for swimming backwards. If the animals are fed, with bits of meat, observe the uses of the various appendages in eating. Some powdered carmine in water may be added at the sides of the cephalothorax, to show that it is passed through the branchial chamber and out at the anterior end.

The two sexes differ in the following external features: the abdomen is wider in the female; the anterior abdominal appendages, rudimentary in the female, are modified in the male into stiff intromittent organs, to convey the spermatozoa of the male to the seminal receptacles of the female; the reproductive openings are at the base of the middle walking legs in the female and of the last in the male.

As in all higher crustacea, the body consists of **nineteen segments**, more or less fused together in the anterior region, each usually with a pair of jointed appendages. The head contains five, the thorax eight, the abdomen six besides the telson, which is here not counted as a segment.

External Anatomy.—Note the nature of the animal as a whole—symmetry, ends, sides, etc.; the **exoskeleton**, consisting of **calcified chitin** and serving for **protection, support** and the **attachment of muscles**; the larger anterior **cephalothorax**, composed of **head and thorax fused together** along the **cervical groove** and covered dorsally and laterally by the box-like **carapace**; the distinctly jointed **abdomen**, terminating in the median **telson**. Lift up the carapace at either side and note that its free edge covers over the **gills**. The head is produced forward between the eyes as the sharp **rostrum**.

Study the third abdominal segment as a typical segment, noting the dorsal (**tergum**) and ventral (**sternum**) shields, and the lateral lobes (the **pleurons**). In one of the appendages, note the basal **protopodite**, bearing distally the inner **endopodite** and the outer **exopodite**.



Begin a figure of a transverse section through this segment, to include the features studied in the preceding paragraph, and put in the internal features after you have finished your dissection of the internal anatomy.

Without trying to make out the details of their structure, note the position, arrangement and nature of the eyes and nineteen pairs of jointed appendages as follows: the large compound **eyes**; the pair of smaller **first antennæ**; the pair of larger **second antennæ**; the pair of strong **mandibles** at the sides of the mouth, followed by the two pairs of very small leaf-like **first and second maxillæ**; the first three pairs of thoracic appendages forming the **first, second and third** pairs of **maxillipeds**; the last five pairs of thoracic appendages forming the five pairs of **walking legs**; the six pairs of **abdominal appendages**, the last much enlarged for swimming.

Note the **external openings**:—the **mouth** on the ventral side, in the centre of the group of small mouth appendages; the **anus**, on the ventral side of the **telson**; in the **male**, a pair of **openings** of the sperm ducts on the bases of the last pair of walking legs; in the **female**, the openings of the oviducts on the bases of the third (middle) pair of walking legs; the openings of the **nephridia** (**green glands**) on the ventral side of the basal joints of the second antennæ.

Draw your specimen from the dorsal and lateral views.

The Gills.—Remove the carapace of the left side and note the feather-like gills within. Study those for the fifth thoracic segment. The gill exposed **on the base of the appendage** is the **podobranch**, and at its base the large, thin lamina is the **epipodite**. Remove these and note the two **arthrobranchs** within, **extending from the joint** between the base of the appendage and the body. In the lobster there is, in addition, a **pleurobranch** within the arthrobranchs, grown out **from the side of the body**. Now go over all of the **thoracic segments** in the same way and make a table to show what you find, of the number of the three types of gills in connection with each segment.

Internal Anatomy.—Remove the whole carapace, including the rostrum; the dorsal third of the skeleton of the abdomen, throughout its whole length; the gills of the left side and the glistening integument just inside of them.

Make a large full-page outline of your specimen from the left side, omitting the appendages. Fill in all of the various features as you proceed with the following dissection.

The Circulatory System.—Carefully tear away the delicate skin of the dorsal side and note the **heart** in the **pericardial cavity** dorsally in the mid-thoracic region. Trace forward from it the median **ophthalmic artery**, to the stomach, head, and eyes; and at its sides, in order, the pair of long **antennary arteries** to the antennæ, green glands and stomach, and the

pair of very short **hepatic arteries** to the large **digestive glands**. From the posterior end of the heart arise the **dorsal abdominal artery** which passes posteriorly to the intestine and surrounding muscles; and the **sternal artery**, which passes ventrally to supply the ventral side of the body. This last artery will be followed later. Note the three pairs of **ostia** in the heart.

Draw the circulatory system, so far as studied, dorsal view. Also, insert it in the large general drawing, begun above.

The Reproductive System.—Having previously determined the sex of your specimen, very carefully remove the heart, dorsal blood vessel, skin, muscles near the box-like stomach, and the weak extensor muscles on the dorsal side of the abdomen.

Sexually the specimens are immature. The pair of **ovaries** of the preserved female are pinkish in color; in the male, the **testes** are white. In either sex note—(1) that the reproductive organs are long and narrow, extending along either side of the stomach and into two or three of the anterior abdominal segments; (2) that they are united by a narrow transverse bridge posterior to the pyloric portion of the stomach.

Identify the ducts on either side slightly posterior to the transverse connection of the reproductive organs. In the female, trace fully the thin-walled, band-like **oviduct** of the left side to its external opening on the base of the middle walking leg; in the male, the thick-walled, coiled **vas deferens**, to its external opening on the base of the last walking leg.

In the male crayfish the testes are fused and Y-shaped, consisting of an anterior bi-lobed portion and a posterior median portion, with the coiled, narrow, thick-walled **vas deferens** on either side. The ovaries of the female are similar to the testes in form, with a pair of wide, thin-walled, uncoiled oviducts.

Draw the reproductive system of your specimen separately, dorsal view. Also insert it in your general drawing.

The Digestive System.—Study the large digestive gland (hepato-pancreas) on either side, consisting of delicate tubes. (Examine with the dissecting microscope.) Note, as other parts of the digestive organs, the esophagus; the stomach, consisting of a large box-like cardiac portion and a smaller pyloric portion; the long uncoiled, straight intestine leading to the anal opening. Carefully cut open the stomach and examine its internal structure. Note nature and relation of the chitinous teeth between the cardiac and pyloric portions of the stomach; the bristle-like strainers in the pyloric portion. Note a green gland, just inside the base of either second antenna. Trace its connection with the external opening. Now review the arteries studied above. Insert the digestive system in your large general drawing, and make a quick separate drawing of it, left view.

The Nervous System.—Carefully remove the whole digestive tract, and the digestive and green glands. Carefully dissect away the great flexor muscles of the abdomen to expose the ventral nerve cord the full length of the abdominal region, on the extreme ventral side. Clear the nerve cord forward through the thorax by chipping away, bit by bit, the skeleton which surrounds the nerve cord of the thoracic region. Trace the connectives around the esophagus to the supra-esophageal ganglion (brain) which, with the eyes, forms an equilateral triangle. Tear away the delicate membranes and other structures which cover the brain in its posterior face. Now study the whole nervous system, noting the supra-esophageal ganglion or brain, with three pairs of nerves to the eyes, first antennæ, and second antennæ; the connectives from the brain around the esophagus to the ventral nerve cord; the sub-esophageal ganglion, with nerves to the appendages grouped around the mouth; the ventral nerve cord in the rest of the thorax and abdomen, with ganglia corresponding to the segments; the paired nerves from these ganglia to surrounding parts.

Draw the nervous system alone, dorsal view, and insert it in your general drawing.

Now trace the sternal artery into its two branches: the ventral thoracic forwards; the ventral abdominal backwards.

The Appendages.—Again go over and identify in place the 19 pairs of appendages, as described on page 60. Beginning at the posterior end, very carefully dissect off the eye and nineteen appendages of one side, and arrange them in order on a sheet of paper in the same relative position, as a series. Be sure to dissect off the whole appendage, right down to the body.

The 19 pairs of appendages of the lobster or crayfish offer excellent material for the study of "serial homology"—the modification in structure of a series of originally similar organs in different ways for different uses. The third abdominal, with its two-jointed protopodite, and its endopodite and exopodite both present, perhaps best indicates the original plan from which the other types have been derived. Study them comparatively, and draw them to the same scale, all $\times 1$, in the case of the lobster, $\times 2$, in the case of the crayfish.

1. **First antenna.** There is a 3-jointed base, and two long, many-jointed filaments. It is doubtful if this appendage is strictly comparable with the others.

2. **Second antenna.** Two-jointed protopodite; endopodite a long filament of many joints; exopodite a short scale.

3. **Mandible.** The first joint of the protopodite greatly developed as the functional jaw; the second joint of the protopodite, with the much reduced endopodite, forms the 3-jointed **palp**; exopodite lost.

4. **First maxilla.** Protopodite of two flat joints; leaf-like endopodite of two joints; exopodite lost.

5. **Second maxilla.** Protopodite of two flat joints; endopodite a filament; exopodite a large, flat bailer to force water over the gills.

6. **First maxilliped.** Protopodite of two flat joints; endopodite and exopodite both present.

7. **Second and third maxillipeds.** Protopodite of two joints; endopodite of five clear-cut joints; exopodite present.

8. **Five walking legs.** Protopodite of two joints; endopodite of same five joints as in second and third maxillipeds; exopodite lost. In the large pinching claw, or **cheliped**, the second joint of the protopodite and the first joint of the endopodite are fused together. (Note that the second and third maxillipeds, and the five walking legs are sharply comparable, joint for joint, except that the exopodite is still preserved in the maxillipeds.)

9. **First abdominal.** In the female rudimentary; in the male, protopodite and endopodite fused into a stiff rod for copulation; exopodite lost. In the male crayfish, the second abdominal also is modified in the same way.

10. **Second to fifth abdominal.** Two-jointed protopodite; endopodite and exopodite filamentous and many-jointed.

11. **Sixth abdominal.** Greatly enlarged and modified for swimming, but with the typical parts shown.

THE FAIRY SHRIMP

Eubbranchipus gelidus or *Streptocephalus sealii*

These beautiful forms are found abundantly in this region in the spring, in shallow ponds and transient pools. In the case of *Eubbranchipus* as soon as the ice has thawed, late in March or early in April, they hatch out from eggs laid the previous spring. They grow rapidly, become adults by the middle of April and die by the middle of May, leaving several batches of their eggs to hatch out the succeeding spring. In the case of *Streptocephalus*, the eggs hatch somewhat later and

the adults live until the middle of June. The larger specimens in alcohol are adults, male (with the large head) and female (with a brood pouch containing eggs on the ventral side when mature). They may be dissected apart, so far as necessary, to make out the various features called for. The smaller immature mounted specimens should be examined for comparison, especially for certain features indicated below.

Note the division of the body into **head**, and **trunk** consisting of **thorax** and **abdomen**. How many segments are thoracic, bearing the **leaf-shaped swimming feet**? How many abdominal, without appendages? Note the pair of large **compound eyes**; between them, the single, small **median eye**; a pair of small **first antennæ**; in the female the stout **second antennæ**, the exopodite only persistent; in the male, the exopodite of the second antennæ greatly modified as a pair of **clasping organs**, with a long coiled, horn-like process (in *Streptocephalus*, very large and branched at the ends) growing forwards from each. On the ventral side of the "neck," note the **labrum** or upper lip; the pair of strong **mandibles**; in mounted specimens 3-4 millimetres long, the small, hook-like **first maxillæ**, and the rudimentary knob-like **second maxillæ**.

The Appendages.—Study the mounted specimens of the thoracic appendages, noting the **endopodite** divided into several lobes, and the **exopodite** consisting of a single large lobe bearing **setae**, but also bearing two thin-walled **branchial lobes** or **gills**, without **setae**, on the outer side of the appendage.

Draw an appendage. Now draw the whole animal from one side.

Cyclops sp.

Cyclops is a representative of the sub-class Copepoda, which are almost always found abundantly in both fresh and salt water the world over.

Note the division of the body into **cephalothorax** bearing appendages, and **abdomen** without. One thoracic segment is **fused with the head**, four are **free**. The **abdomen** consists of five segments, the first two fused together in the female. Note the small "**cylops eye**"; the large **first antennæ**, modified somewhat into **claspings organs** in the male; the smaller **second antennæ**.

With high power, study one of the thoracic appendages in an animal turned ventral side up. Note **protopodite**, **endopodite** and **exopodite**. What do you make of the pair of appendages of the last thoracic somite?

In the digestive system note the **mouth**, leading into the **crop**. The crop passes into the **intestine**, whose rhythmic contractions cause a simple movement of the **celomic fluid**, since a heart is absent. The **excretory system** consists of a pair of coiled **shell-glands** lying in the cephalothorax.

In the female note the single median **ovary**; at its sides, the **oviducts** which often contain eggs, and lead to a pair of large external **oviscas** containing eggs.

Draw the animal from dorsal view.

THE FIDDLER CRAB

Uca sp.

The fiddler-crabs are marine shore forms and are found in most parts of the world in great numbers.

Examine carefully the external characters of a **male fiddler-crab (with the large pincers)**. Compare with the same appendage of the lobster or crayfish and make note of the resemblances and differences you observe. Compare the female with the male, observing especially the abdomen and its appendages. Make note of the differences. How do you account for the differences between the two?

Draw the male from the dorsal view and the female from the ventral, x 2.

A CENTIPEDE

Scolopendra sp. or *Lithobius* sp.

The small specimens are of our native *Lithobius*. They are found abundantly under boards and in other damp, dark places, where they feed upon insects and other small animals. The large specimens of *Scolopendra* are from the Philippines.

Note the division of the body into **head** and **trunk**, the latter not specialized into thorax and abdomen, but composed of a series of more or less similar segments, each bearing a pair of jointed appendages. On the head, note the **eyes**, each composed of a number of **ocelli**; the **antennæ**, or first pair of appendages; the pair of **mandibles**; the **first** and **second** pairs of **maxillæ**, the last bearing the **palps**, and fused together to form the lower lip; the **mouth**. Note the modified first trunk segment with its appendages modified into the **poison claws**; the other trunk segments, except the last, each with its pair of typical appendages; the last one with its elongated appendages serving especially as tactile organs; the **anus**; the **stigmata** or breathing pores, on alternate segments.

Draw dorsal and ventral views of the head and anterior three trunk segments; and dorsal view of the posterior four, numbering all of the segments.

THE GRASSHOPPER

Schistocerca americanum and *Romalea microptera*

The specimens for study are of two large Southern grasshoppers which are chosen because of their large size. The very large form, with small wings, is the "lubber grasshopper." Any of our common native grasshoppers would show the same structure and serve the same purpose, but they would be more difficult to study because of their smaller size. You should go into the field and get various kinds of grasshoppers for

yourself, so as to understand their habitats, habits, food-plants, etc. Catch and keep some specimens, observing their activities, breathing movements, etc.

The grasshopper as an insect, along with the crustacea (illustrated by the crayfish and lobster), spiders, and centipedes belongs to the great phylum or branch of the Animal Kingdom known as the Arthropoda. The animals belonging to this phylum possess the following characteristics in common:

1. They are covered by a hard chitinous **exoskeleton** or external skeleton. This skeleton serves for protection of internal organs, for the attachment of muscles, and for support.
2. They are **segmented**, as is the earthworm, but differ from the latter in that the segments are unlike in the different parts of the body, resulting in the formation of three distinct regions, **head, thorax** and **abdomen**.
3. They possess **jointed appendages**, a pair to a segment where they are present.

The grasshopper belongs to the group **Insecta**, one of the **classes** or divisions of the Arthropoda. The animals belonging to this class have the following characteristics:

1. They possess **three pairs of legs** and hence are often known as the **Hexapoda**.
2. They possess typically **two pairs of wings** for flight, borne upon the dorsal side of the second and third segments of the thorax.
3. They breathe by means of a much-branched system of internal tubes known as **tracheæ** which convey air containing oxygen to all parts of the body. The breathing pores are the **spiracles** or **stigmata**, arranged in pairs on the outside.

The Grasshoppers, along with crickets and cockroaches, belong to the order **Orthoptera**. They are characterized by possessing mouth-parts or jaws formed for biting and gnawing; and by possessing two pairs of straight wings, the first

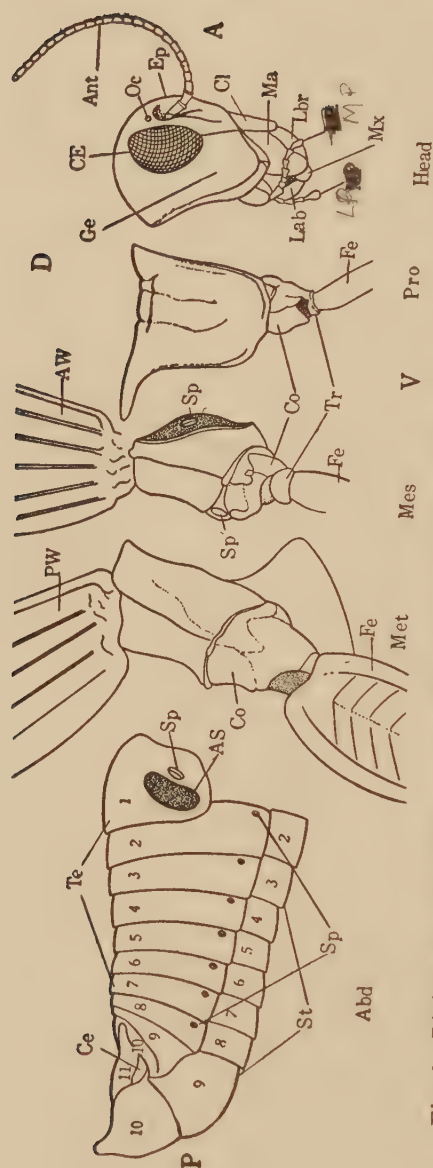


Fig. 9—Right view of a male grasshopper (*Melanoplus spretus*). The body is separated into three regions of head, thorax and abdomen, and the three thoracic segments are separated from each other. (After Packard.)

A, anterior end; **Abd**, abdomen; **Ant**, antenna; **AS**, auditory sac; **AW**, anterior wing; **Ce**, compound eye; **Cl**, clypeus; **Co**, coxa, the basal joint on the three pairs of legs; **D**, dorsal; **Ep**, epicranium; **Fe**, femur, the large joint in the three pairs of legs; **Ge**, Gena; **Lab**, labium or lower lip, composed of the pair of second maxillae fused together; **Lbr**, labrum or upper lip; **LP**, labial palp or feeler of the labium; **Ma**, mandible; **Mes**, mesothorax, the second or middle thoracic segment; **Met**, metathorax, the third or last thoracic segment; **MP**, maxillary palp or feeler; **Mx**, first maxilla; **Oc**, ocellus or simple eye; **P**, posterior end; **Pro**, prothorax or first thoracic segment; **PW**, posterior wing; **Sp**, spiracles, breathing pores in most of the segments; **St**, sternum or ventral plate in the various segments; **Te**, tergum or dorsal plate in the various segments; **Tr**, trochanter, the second joint in the three pairs of legs; **V**, ventral; **1-11**, first to eleventh segments of the abdomen. (After Packard.)

pair thickened, the second pair thin and folded like a fan under the first pair when at rest.

Carefully follow the directions below in your study of the external anatomy of the grasshopper, using the accompanying figures as helps.

Directions and Relations in the Body.—Note **anterior** and **posterior ends**; **dorsal** (back) and **ventral** (belly) **surfaces**; **right** and **left sides**; that the animal is **bilaterally symmetrical**—that a median, vertical, longitudinal plane would divide the animal into similar right and left halves.

Divisions of the Body.—Note the division of the body into three well-defined regions: the movable **head**; the **thorax** bearing the legs and wings; the **abdomen**.

The Head.—On the head, note the pair of jointed **antennæ** or **feelers**; a pair of large **compound eyes**; three **ocelli** or **simple eyes**, a pair between the compound eyes and antennæ and a single median one in the center of the forehead.

The mouth-parts or jaws will be studied in detail later. Note their position and general character at present, as follows: the **labrum** or upper lip; the pair of heavy, strong, biting **mandibles**; the **first pair of maxillæ**, with feelers or palps at the sides; the **second pair of maxillæ**, fused together to form the **labium** or lower lip. The regions of the head may be identified by reference to the figure, but need not be drawn or memorized.

The Thorax.—Note the three segments of which the thorax is composed, **prothorax**, **mesothorax** and **metathorax**; the **three pairs of jointed legs** attached to the ventral side of the three segments; the **anterior** and **posterior pairs of wings** attached to the dorsal side of the mesothorax and metathorax. Examine the wings, noting form, consistence, color, etc.; the **longitudinal** and **cross veins**.

The Abdomen.—Note the **eleven segments**, as illustrated in the accompanying figure, the posterior ones not so complete and clearly defined; in any one of the middle segments, the

tergum, or dorsal plate of the ring and the **sternum** or ventral plate; the **spiracles** or **breathing pores** (look for those on the thorax also). On the first abdominal segment, note the pair of **auditory organs**.

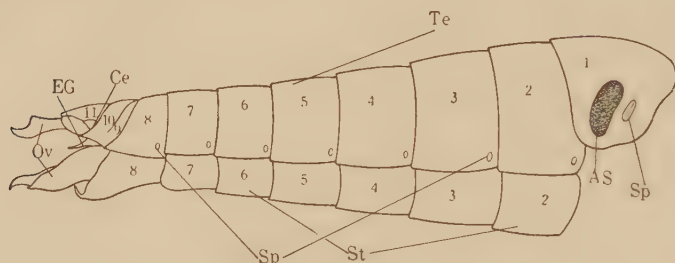


Fig. 10—Right view of the abdomen of a female grasshopper (*Schistocerca americanum*) to show especially the egg-laying apparatus. x3.

AS, auditory sac; **Ce**, cercus; **EG**, egg-guide, **Ov**, ovipositor; **Sp**, spiracles of the various segments; **St**, sternum in the various segments; **Te**, tergum in the various segments; 1-11, first to eleventh segments of the abdomen.

In the female note the dorsal and ventral pairs of **ovipositors**, with which the animal works a hole in the ground to lay the eggs.

The Thoracic Appendages.—The first two pairs of legs of the grasshopper are **walking legs**, the third pair **jumping legs**.

Study the first walking leg and note its division into five regions as follows: the **coxa**, a short joint next to the body; the **trochanter**, a small joint; the long, stout **femur**; the long, narrow **tibia**; the **tarsus**, composed of three joints. Carefully examine the spines and claws upon this leg and determine their purposes.

Examine one of the large jumping legs, noting the same regions as in the first leg.

The External Openings.—Note the **mouth** in the center of the mouth-parts, and the **anus** at the posterior end.

Make the following drawings of your specimens:

1. From the left side representing the first leg as extending forwards, the second and third backwards; and representing the wings as not present; $\times 2$ or 3.
2. Dorsal view, representing the right wings as fully spread out and extended out at the side, and the three left legs as extended at the left side, $\times 2$ or 3.
3. The first and third legs, $\times 4$.

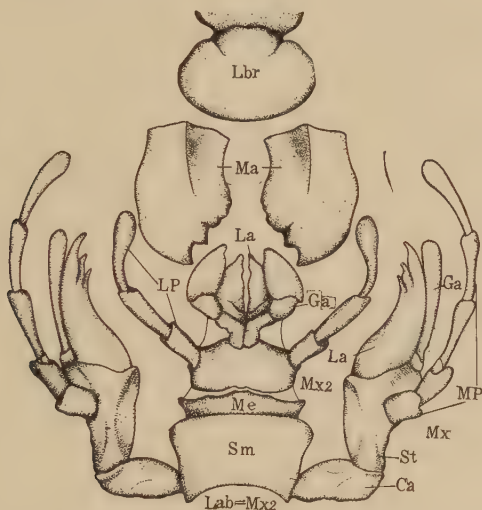


Fig. 11—The mouth-parts of a male cricket. The labrum and mandibles are drawn anterior view; the first maxillæ and labium, posterior view and somewhat flattened out. $\times 6$.

Ca, cardo; Ga, galea; La, lacinia; Lab, labium or lower lip, composed of the pair of second maxillæ fused together; Lbr, labrum or upper lip; LP, labial palp; Ma, mandible; Me, mentum of the labium, composed of the two stipes fused together; MP, maxillary palp; Mx1, first pair of maxillæ; Mx2, second pair of maxillæ, fused to form the labium; Sm, submentum of the labium composed of the two cardos fused together; St, stipes.

The Mouth-Parts.—The mouth-parts of the insects are modified jointed appendages and derived from the same general plan as the walking legs. In adaptation to their new func-

tion of securing and masticating the food, they have undergone considerable modification in forms like the grasshopper; but much greater modification in most insects, where they are used for sucking, piercing, etc.

Three pairs of appendages have been modified into **jaws** or **mouth-parts**. In addition to these, a flap has grown down over the mouth from in front, known as the **labrum** or upper lip.

Using the mounted specimens of the mouth-parts of the cricket and referring to the figure in the Guide, make a careful study with the dissecting microscope and low power. Identify and study all of the parts.

Now again identify the mouth-parts of the grasshopper in place. Dissect them off carefully, arrange them in order, and make a careful study, comparing with your study and the figure of the mouth-parts of the cricket. Note any differences.

Make a drawing x8, arranging somewhat as in the figure in the Guide, and labeling all structures.

Development of the Grasshopper.—Our common grasshoppers hatch in the spring as “nymphs,” from eggs laid in the ground the previous autumn, in almost the adult form, but lacking the wings. At the 5th moult, they acquire the full size, with wings. They illustrate, therefore, “development with incomplete metamorphosis” (**heterometabolous development**).

Note the features of a nymph, and draw from the left side, x2.

THE ELECTRIC-LIGHT BUG

Benacus griseus

This is one of the giant water-bugs. It belongs to the order Hemiptera, with piercing mouth-parts and the anterior

wing specialized into a hard half next to the body and a membranous half away from the body.

It is an aquatic form, living in ponds and lakes. It swims fairly well by means of the third pair of jointed legs, which are flattened to serve as oars. From time to time it flies from one pond to another and is oftentimes found around bright lights, whence the vernacular name.

This form is carnivorous, living upon small aquatic animals of various kinds. For this reason the mouth-parts are modified into a beak for piercing into the flesh of the prey and sucking out its contents. Also, the first pair of legs are modified for seizing and holding the prey.

Make a careful study of this insect in all its parts, comparing with your study of the grasshoper. Note resemblances and differences.

Draw dorsal view, x2, representing the wings spread out on the right side, and the legs extended on the left side.

Draw also one of the first legs to illustrate grasping legs and one of the third to illustrate swimming legs. ...Both x4.

THE MOURNING CLOAK BUTTERFLY

Eu Vanessa antiopa

This beautiful butterfly and its life history will typify for us the order Lepidoptera (butterflies and moths). They are characterized by two pairs of large wings covered with scales; mouth-parts modified into a long sucking tube; complete metamorphosis, with caterpillar larva. The "mourning cloak" is found widely in the north temperate zone; passes the winter as the adult butterfly; lays its eggs upon willows, elms, etc., in May; hatches in a couple weeks; grows rapidly and moults four times; attains its full size as a black spiny caterpillar in a few weeks; becomes a naked pupa; and emerges in about two weeks as a butterfly, late in June. A second brood

follows later in the summer. Our specimens include the full-grown caterpillar in the glass tubes; and the well-formed pupa, pupa case, and adult butterfly in the mounted case. This form illustrates, therefore, "development with complete metamorphosis" (**holometabolous development**), passing through the stages, egg, larva, pupa, adult.

In the **butterfly**, note the general characters of insects; the two pairs of large, **membranous wings**—their form, veins, color above and below; club-shaped **antennæ**; two pairs (only) of well-developed **legs**, the first of the three pairs being rudimentary; the long **proboscis**, coiled like a watch-spring.

Draw, dorsal view, natural size.

In the **caterpillar**, note **head**; **body** covered with **spines**; **thorax** of three segments, with three pairs of **legs**, corresponding to the three pairs of adult insect legs; **abdomen**, with five pairs of (larval) **prolegs**.

Draw, side view, x 1.

In the **pupa**, note that it is suspended from the posterior end; its naked (uncovered by cocoon) character; spiny dorsal **side**; wings, antennæ, and mouth-parts faintly shown on the ventral side.

Draw ventral or side view, x 2.

The Tobacco Worm.—The specimens for detailed study of a caterpillar are the "tobacco worms" so destructive to tobacco where it is grown. They are chosen because of their large size and the clearness with which the various features of structure can be made out. These caterpillars grow rapidly and, when full-grown, go into the ground to become pupæ. The larger specimens for study are of about full size.

Examine your specimen carefully throughout. Note the worm-like body, divided into **head**, covered with a smooth, hard exoskeleton; **thorax**, composed of three segments, bearing the three pairs of jointed legs; **abdomen**, the rest of the body composed of nine segments, some of which bear **prolegs**. Note the **mouth** in the midst of the mouth-parts; the

anus above the last prolegs, under a sort of lip; the **spiracles**, in certain of the segments—determine their number and location; **spine** at the posterior end.

In the head note, as parts of the **mouth-parts**, without trying to make out their details, the **labrum** or upper lip; the heavy, black, biting **mandibles**; the **antennæ** and first **maxillæ** lateral to the mandibles; the **second maxillæ**, fused to form the **labium** or lower lip. Note the six pairs of **ocelli** or simple eyes lateral to the first maxillæ.

Draw your specimen from the left side, **x2**, naming all the parts. Also, draw a left view of the head and first thoracic segment, **x6**.

A COMMON FLY

The house-fly or any other of our common flies illustrates the characters of the order **Diptera**, with one pair of wings, sucking mouth-parts, and complete metamorphosis.

In the adult fly, note the very general characters of insects; the large **eyes**; the single pair of **wings** on the mesothorax; the **rudiments** of the second wings on the metathorax.

Draw, dorsal view, x8.

The Maggot of a Fly:—Common flies pass through a very degenerate worm-like larval stage called a **maggot**. From the complete absence of legs of any kind it is called an **apodiform larva**. The eggs are laid in decomposing matter of some kind, and quickly hatch as maggots which rapidly attain full size, usually in a week or so. They then crawl off to some secluded place to pupate. In a week or so the fully developed fly emerges from the pupa. The specimens for study are larvæ of one of our common blow-flies. The eggs are laid in dead flesh and hatch out in 24 hours as maggots which attain their full size in a few days.

Examine this larva carefully and note the poorly defined division of the body into regions: the very small **head**, bear-

ing a pair of ventrally curved black hooks; the **thorax**, consisting of three segments; the **abdomen**, of eight. Note the pair of small spiracles on the second thoracic segment and a second pair in the posterior end.

Draw your specimen from the right side, x6. Name all structures shown in your drawing.

THE KING CRAB

Limulus polyphemus

Specimens of the king crab are found abundantly on our Atlantic coast, the different sizes, of different ages, being found in different habitats. The specimens for study are about a quarter grown.

Note the **cephalothorax**, covered by the **carapace**; the **abdomen**; the **caudal spine**. In the cephalothorax note the pair of large **compound eyes**; a pair of small **simple eyes** at the sides of the frontal spine; the six pairs of **cephalothoracic appendages**, their bases modified into jaws or **gnathobases** for the mastication of food. What comparison in structure, position, and function with those of the crayfish and scorpion? Note the **mouth**, surrounded by the **gnathobases** of the appendages; and **anus**, under the **caudal spine**.

In the abdomen note the first pair of appendages modified into a **genital operculum**, with the pair of **genital openings** on the posterior side; the next five pairs of appendages modified into **covers** for the **gill-books**.

Draw a dorsal view.

A SCORPION

Euscorpio sp.

The large specimens of Scorpion are from the Philippines, the smaller ones from other sources. The various species are interchangeable for purposes of general study.

Note the division of the body into the smaller **cephalothorax** bearing the four pairs of walking legs; the larger **abdomen**, without appendages, composed of an enlarged **mesosoma** and a narrow **metasoma**.

On the cephalothorax note the **carapace**; the **lateral** (near the anterior dorsal surface) and the **median** (near the center of the carapace) **eyes**; the **mouth**; the small chelate **chelicerae**; the large **pedipalps**, large pincers similar to those of the lobster; the **four pairs of walking legs**. On the mesosoma note the **genital operculum** on the first segment; the **pectines** on the second; the **stigmata** opening to the **lung books** in the 3-6 segments. Note the **anal opening** on the ventral side at the end of the fifth metasomatic segment, and the terminal **poison sting**.

Draw the animal, ventral view, and a dorsal view of the carapace.

A SPIDER

Epeira sp.

Any of our larger common spiders may be used for study. The large specimens usually found are females, the males being much smaller.

Note the division of the body into **cephalothorax** and **abdomen**. Do you find any evidence of segmentation in the latter? Note the **eyes** (how many pairs?); the **mouth**; the pair of two-jointed **chelicerae**; the large, leg-like **pedipalps**—their nature; the **four pairs of walking legs**, each ending in a pair of hooks. How many joints in the walking legs? On the ventral side of the abdomen note the **operculum**, which shields the **reproductive opening**, near the anterior end; just posterior to it, the pair of openings into the **lung books**; near the posterior end, the three pairs of **spinnerets**, and just posterior to the last pair, the **anal papilla**, with the **anal opening**.

Draw a ventral view, $\times 4$; a large dorsal view of the cephalothorax, $\times 8$; and one of the walking legs, $\times 8$.

CHAPTER X

PHYLUM ECHINODERMATA

THE COMMON STARFISH

Asterias forbesii

The specimens for study are from the Atlantic coast, where they are sometimes abundant in certain localities. They retain their natural color and appearance fairly faithfully. Alternate specimens have been injected with yellow or red fluid to bring out more clearly the water-vascular system, especially the tube-feet. The sexes are separate, but without pronounced external differences.

External Anatomy.—Note the central disc and the rays or “arms”; the ventral (oral) and dorsal (aboral) surfaces; the yellow madreporite. The two rays adjacent to the madreporite form the bivium; the remaining three the trivium. Is there strict radial symmetry? Note the body-wall or hard integument, containing the calcareous ossicles, many of which bear spines. Examine these spines in the various parts of the body and note any specializations among them, both as to their nature and arrangement.

Note, on the ventral side, the mouth in the center of the disc, and surrounded by the buccal membrane or peristome; the ambulacral grooves on the ventral side of the arms, radiating from the center; in the grooves the tube-feet, each a small tube terminating in a sucker; the orange-colored eyespot, at the tip of each ray. Look for the small pedicellariæ (best seen in dry specimens), little pincers, especially at the base of the spines; the delicate dermal branchiæ, as small, delicate, hollow outgrowths of the body-wall from the surface (shown best dorsally in injected specimens).

Draw dorsal and ventral views, putting in the details of the disc and bivium, but only the outlines of the other rays, x 1. Also make a careful large drawing of a small portion of the dorsal surface.

THE SEA-URCHIN

Arbacia punctulata and *Strongylocentrotus* sp.

The two species used for study are both Atlantic coast forms, the black specimens (*Arbacia*) from Massachusetts; the green ones (*Strongylocentrotus*) from Maine. Males and females are not distinguishable externally.

External Anatomy.—Note the body-wall in the form of a firm, more or less globular shell; on the ventral side the mouth surrounded by the five ivory-like teeth of the “**Aristotle’s Lantern**,” outside which is the membranous **peristome**; the **anus** in the center of the dorsal side, and surrounded by the four movable **anal plates** which constitute the **periproct**. Study one of the spines. Note that it is movable and that the **socket** at its base articulates with a **ball** upon a plate, forming a “**ball and socket joint**.” Are any of the spines specialized? Where? Why? Note the tube-feet projecting from the ambulacral pores of the shell, ten of them on the peristome especially enlarged. Look for the **pedicellariæ**, little pincers, among the spines, and especially on the peristome.

Study the aboral part of a shell from which the spines have been removed. Note the five double rows of **ambulacral plates**, perforated by the **ambulacral pores**; between them the five double rows of **interambulacral plates**; at the tips of the latter, the **genital plates**, each with a **genital pore** and one of them modified to form the porous **madreporite**; at the tips of the rows of ambulacral plates, the **ocular plates**.

Draw the aboral quarter of the shell.

CHAPTER XI

PHYLUM MOLLUSCA

THE FRESH-WATER MUSSEL

Anodonta sp. or *Unio* sp.

One or more species of fresh-water mussels are usually found in the lakes and streams of localities in which there is sufficient lime in the water to enable the animal to form its shell. Almost any of these will answer for purposes of study. Our specimens are common forms from nearby lakes and streams.

The Shell and External Anatomy.—In the bivalve shell note the two valves, hinged together along the dorsal side, gaping along the ventral; the anterior (smaller) and posterior (larger) ends; the right and left sides. Study the external features of one valve of the shell, noting the umbo, the small part of the shell first formed; the concentric lines of growth, the larger ones indicating years; the hard, greenish covering, the periostracum, often worn off from the umbo of older specimens.

Remove the animal from the shell by carefully loosing the mantle and the various muscles from both valves by means of a large scalpel, with the blade kept close against the shell, so as not to injure the parts of the animal. The large space within the mantle is the mantle cavity.

Examine your specimen under water and study the mantle, with its thickened edges; the pallial muscles, delicate radiating muscles of the mantle near its edge; the hatchet-shaped foot, pointing towards the anterior end; the very large single anterior and posterior adductor muscles; a pair each of anterior and posterior retractor muscles, much smaller than

the adductors and somewhat dorsal to them; the pair of protractor muscles, somewhat ventral and posterior to the anterior adductor; the wall of the pericardium, the thin part of the mantle just in front of the posterior adductor muscle; the inhalent (vētral) and exhalent (dorsal) siphons, formed by appositions of the mantle of the two sides of the posterior end.

Now observe the inner face of the shell valves and note the "mother-of-pearl" layer of the shell; the pallial line along which, in life, the pallial muscles are attached; the muscle impressions, points of attachment of all the various muscles studied above; the hinge ligament—is it compressed or stretched by the action of the adductors? In Unio, note the large hinge teeth.

Draw the left valve, external view; the right valve, internal view, drawing and labeling all of the muscle impressions studied above; and the animal as removed from the shell, from the left side, all x 1.

Carefully dissect away the mantle of the left side to its line of attachment. Note the foot; the internal and external gills, larger laminæ nearer the posterior end; the internal and external labial palps, smaller laminæ near the anterior end at the sides of the mouth; the mouth, only an aperture, without jaws of any kind, under the anterior adductor muscle.

Draw your specimen, x 1.

Internal Anatomy.—Make a large six-inch outline of the animal from its left side, with outlines of the mantle, foot, and adductor muscles for landmarks. Put in the features studied below as you dissect them. Lay the animal dorsal side down. Separate the two internal gills from each other where they are fused behind the foot. Note that the septum formed by their fusion on the midline divides the mantle cavity into a small epibranchial cavity dorsal to the septum and a large hypo-branchial cavity ventral to it. Very carefully dissect away the delicate skin from the ventral surface of the posterior

adductor muscle and note the yellowish, rectangular **visceral ganglion**, composed of a pair of ganglia of the two sides fused together. Note the three pairs of nerves from the visceral ganglion:—the larger **pallial nerves** going to the mantle; the **branchial nerves** to the gills; and the small **cerebrovisceral connectives** running forwards on either side to connect the visceral with the cerebral ganglion. **Make a separate small ventral-view of the visceral ganglion and its nerves, x 12.**

Lay your specimen upon its right side under water and dissect off the left pericardial wall, being very careful not to injure the structures within the **pericardial cavity** (i. e., the true **body-cavity or celom**). Within the pericardial cavity note the **rectum**, surrounded by the thick-walled **ventricle** of the **heart**; on either side a very delicate, fan-shaped **auricle** entering the ventricle. Trace the rectum over the posterior adductor, to end in the **anus**.

Add these features to your large drawing.

Pin the specimen down, dorsal side up. Dissect away the rest of the dorsal wall of the pericardial cavity. Cut across the rectum near the posterior end of the pericardial cavity and pull it forward, noting the “**bladder**” portion of the **kidney**, which forms the floor of the pericardial cavity. At the anterior angles of the floor of the pericardial cavity note the pair of small slit-like **internal openings** leading from the pericardial cavity to the kidneys.

Lay the specimen on its right side. Very carefully dissect away the palps and gills of the left side along their lines of attachment. Note the very small slit-like **external kidney opening** between the internal gill and the visceral mass, just ventral and external to the internal opening. Just ventral to the kidney opening is the small **reproductive opening**. Now trace one of the kidneys throughout its course. It begins in the opening from the pericardial cavity; passes posteriorly through the ventral dark, thick-walled **secretory portion**; bends dorsally upon itself in front of the posterior adductor

muscle; passes forward through the dorsal, thin-walled **bladder portion**; and opens to the exterior.

With the aid of an instructor, cut your specimen through the mid-plane, into right and left halves with a sharp razor. Most of the digestive tract lies in the midplane, and is now exposed. So far as is necessary, dissect it further as you proceed.

Note the jawless **mouth** under the anterior adductor; the **short, flat esophagus**; the small **stomach**; on either side of the stomach, the greenish **digestive gland** or "liver"; the long, looped **intestine**, of which the last part is the **rectum**, already studied; the yellowish **reproductive organ**, packed around the intestine and occupying a large part of the foot.

Add these features to your large drawing.

Dissect away the skin at the left side of the mouth and observe the small yellow **cerebral ganglion**, smaller than the visceral and connected with its fellow of the right side by a long commissure anterior to the esophagus. Nerves from it go to the adjacent palps and mantle. Find the **pedal ganglion** in the foot, exposed when the animal was cut into halves. So far as time permits, trace the **connectives** on one side from the cerebral ganglion to the pedal and to the visceral ganglia.

Finish your large drawing.

Study of Transverse Sections.—1. Through the heart. Using the accompanying figure as a guide, get an accurate interpretation of this section. Note the various structures as already studied—the **mantle fold** on either side, with its thickened edge; the **mantle cavity**, divided into the **epibranchial cavity** dorsal, and the **hypobranchial cavity** ventral, to the gills; the **external gill**, with its **external limb** attached to the mantle; the **internal gill** with its **internal limb** attached to the foot; the **pericardial cavity**, containing the **rectum**; the **typhlosole**, a ridge of the rectum projecting into its cavity; the thick-walled **ventricle** surrounding the rectum; the **auricles** attached to the ventricle; the upper and lower limbs of the **kidneys**; the **foot**, containing the reproductive organs surrounding sections of the intestine.

Draw, representing the mantle folds in their normal shape and the shell-valves and ligament as if in place.

2. Section anterior to the heart. Study and draw carefully, naming all parts.

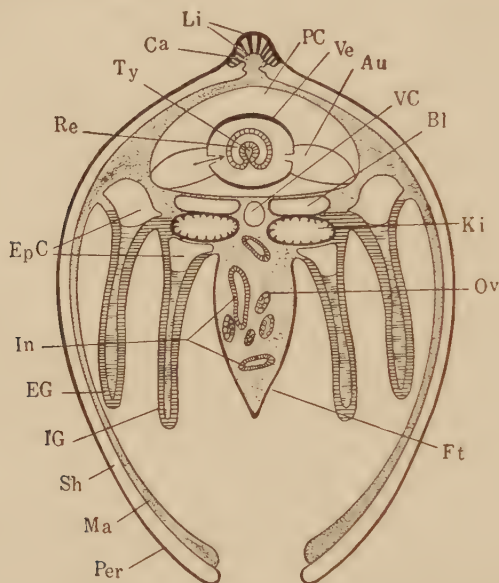


Fig. 12—Transverse section of the fresh-water mussel through the middle of the heart, slightly diagrammatic. The arrow head is inserted in the aperture from the auricle to the ventricle and indicates the direction of the circulation.

Au, auricle of the heart; **B1**, upper limb or bladder portion of the kidneys; **Ca**, the elastic "cartilage" of the hinge-ligament; **EG**, external gill, its external limb fused with the mantle; **EpC**, epibranchial cavities above the gills; **Ft**, muscular foot; **IG**, internal gill, its internal limb fused with the foot; **In**, intestine in foot; **Ki**, lower or secretory limb of the kidney; **Li**, hinge-ligament, a greatly thickened portion of the periostracum uniting the two shell valves and differentiated into an outer inelastic portion, and an inner compressible portion composed of radiating fibres; **Ma**, mantle; **Ov**, ovary; **PC**, pericardial cavity (the real body-cavity); **Per**, the horn-like periostracum covering the shell valves and thickened over the hinge; **Re**, rectum, the terminal part of the intestine, passing through the pericardial cavity and surrounded by the ventricle of the heart; **Sh**, shell; **Ty**, typhlosole as an indenting ridge extending into the intestinal cavity; **VC**, vena cava; **Ve**, ventricle.

3. **Section through the posterior adductor muscle. Study and draw carefully, naming all parts.**

The main features of the circulatory system may be studied from the injected and dissected demonstration specimens. So far as time permits, transverse sections in other regions may be studied; also sections of the gills for the details of structure.

THE SQUID

Loligo pealii

There are several species of squids along the American coasts. The species to be studied is the most abundant. They are powerful and active. They may crawl along by means of the arms or swim slowly forward by means of the fins. They may swim backward with great rapidity by sucking water into the mantle cavity and sending it out with great force through the siphon.

External Features.—Note the **physiological anterior** (with the arms) and **posterior ends**; **dorsal and ventral sides**; **head, neck and trunk**. On the head, the “**arms**” (how many? kinds? arrangement?); the **suckers** (arrangement?). Make and sketch a vertical section of a sucker, noting **stalk, horny ring and piston**. How do you think the sucker works? Note the mouth in the center of the arms, with **dorsal and ventral beaks**; the **eyes (eyelids?)**; the **olfactory organ** as a fold on either side back of the eye. Note the very thick **mantle around the trunk**; the **collar**; end of **siphon**; **fins**; **chromatophores** or color spots in the skin (distribution?).

Draw a dorsal view. Also from the left side if your time permits.

The Mantle Cavity.—Open the mantle cavity by cutting the mantle slightly to the left side of the mid-ventral line

from the collar to near the posterior end. Note, as you proceed, the very thick muscular mantle; the relations of the mantle to the parts within the mantle cavity; the **mesentery**, from the **visceral mass** to the mantle.

Carefully examine the contents of the mantle cavity. Note the funnel-shaped siphon; its **retractor muscles**; the **blind sacs** at the sides; the **cartilages** of the siphon and of the mantle adjacent (their relation to each other). Note the prominent **gills** (nature? attachment?); the **branchial hearts** at their base; the **rectum** with the **ink-duct** and **ink-bag** dorsal to it; the **anus**; the small **nephridial pores** at the sides of the rectum; in the male, the **penis** on its left side; in the female, the pair of thick-walled **nidamental glands** at its sides and the single wide end of the **oviduct** on the left side; in both sexes the large **visceral mass** consisting of parts of the **digestive** and **reproductive systems**.

In an injected specimen note, as parts of the circulatory system, the pair of large **glandular-walled pre-cavæ**, veins returning blood to the branchial hearts, and arising from the single precava under the rectum, which receives its blood from the head; the pair of large **post-cavæ** from the posterior part of the mantle, entering the branchial hearts posteriorly; the pair of smaller **lateral mantle veins** from the mantle anteriorly; the single **median mantle artery** passing in the mesentery to the mantle; the pair of **lateral mantle arteries**, coming off from the **posterior aorta**.

Make a large drawing of the mantle cavity and its contents so far as you have studied them.

CHAPTER XII

PHYLUM CHORDATA

THE LANCELET

Branchiostoma sp.

A dozen or so species of small fish-like forms constitute the sub-phylum Cephalochorda. They almost completely meet our ideal of the primitive ancestral vertebrate. They are all marine, live buried in the sand, and usually are called "amphioxus" or "the lancelet."

The specimens in tubes, in whole amounts and in transverse sections, represent various species from the coasts of California, Italy, and Africa, but they are quite interchangeable for purposes of study. The white specimens have preserved their natural color and appearance fairly faithfully. The larger specimens in dishes and tubes are sexually mature; the mounted whole specimens are sexually immature.

External Anatomy.—In the white specimens in alcohol, note the spindle-shaped **body**, with the **absence of head**, and of **paired fins or limbs**; at the anterior end, the **mouth** leading in to the **mouth cavity**, which is surrounded by the **oral hood** fringed with the **tentacles** or **cirri**; the **atriopore** at the junction of the middle and posterior thirds of the body; the **anus** on the left side of the **ventral fin**; the **dorsal** and **ventral fins**; on the ventral side, the rounded **metapleural folds**, giving to the anterior two-thirds of the body a triangular shape in transverse sections; the division of the great **longitudinal muscles** into the V-shaped **myotomes** or **muscle segments**; the **reproductive organs**, 26 pairs of swellings in the middle third of the body, (31 pairs in the large species in tubes).

Draw from the left side, x2 or 3.

Internal Structure.—In the mounted whole half-grown specimens note, in addition to the features observed above, the

notochord, extending throughout the length of the animal; dorsal to it, the **nerve-tube** or **spinal cord**, with the very small pigmented **eye-spot** at its extreme anterior end; a row of **pigment spots** ventral to the nerve-tube.

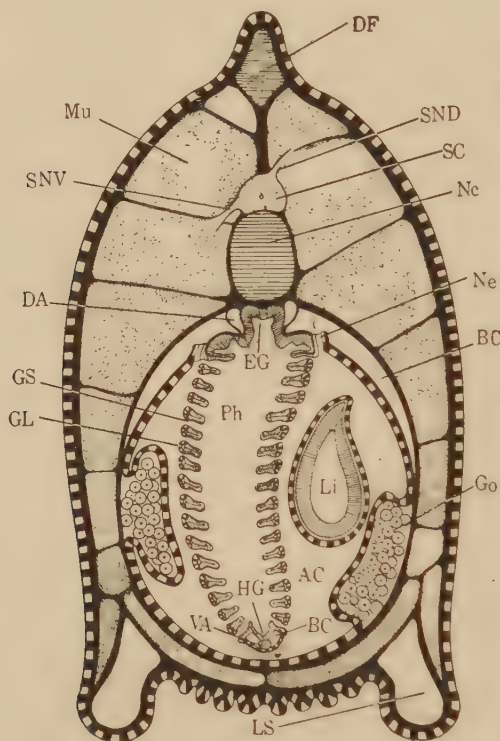


Fig. 13—Transverse section of a female amphioxus through the region of the pharynx and liver. The ectoderm throughout is represented in black and white check; the endoderm, lining the pharynx and liver, as finely striated; the muscles in fine dots; the supporting tissue which surrounds the notochord, extends between the muscles, and underlies the surface epithelium, is in black. x30. (Modified from Hertwig, after Lankester and Boveri.)

AC, arterial cavity; BC, body-cavity; DA, dorsal aorta; DF, dorsal fin; EG, epipharyngeal groove; GL, gill lamella or bar; Go, reproductive organ (in this case ovary with egg cells); GS, gill slit; HG, hypopharyngeal groove or endostyle; Li, liver; LS, lymph space; Mu, muscles; Nc, notochord; Ne, nephridia; Ph, pharynx; SC, spinal cord; SND, dorsal spinal nerve; SNV, ventral spinal nerve; VA, ventral aorta.

Belcham + Ten B...

In the alimentary tract, note the buccal or mouth cavity; the very large pharynx, with the oblique gill-bars, separating the gill-slits; the intestine, terminating at the anus; the liver, a single large finger-shaped tubular diverticulum from the intestine, extending forward along the right side of the pharynx.

Make a 6-inch semi-diagrammatic figure from the right side to show these internal features.

Study of Transverse Sections.—The prepared slides include selected sections through five or six regions, of which the five indicated may be chosen as the most essential for study. At least some of the sections are through the ovaries of a female specimen.

1. Through the pharynx in the region of the liver and reproductive organs. Using the accompanying figure for reference, make a very careful study. Note the epidermis consisting of a single layer of cells; the notochord, with its tough sheath from which extend the septa that separate the myotomes and are continuous with the connective tissue under the epidermis; the nerve-tube, with its central canal, its nerve cells and nerve fibers, some of which are larger giant fibers. Look for spinal nerves from the nerve-tube. Note the atrial cavity surrounding the pharynx; in the wall of the pharynx the larger primary gill-bars and the smaller secondary; the ventral side of the pharynx modified as the grooved endostyle lined by long ciliated cells; the epipharyngeal groove on the dorsal side; the reproductive organs (female in the prepared sections) pushing out into the atrial cavity, with typical ova of various sizes of growth. Note the celom, shown as paired cavities at the sides of the epipharyngeal groove and a single space ventral to the endostyle; the paired dorsal aortæ and the single ventral (cardiac) aorta. In one of the larger primary gill-bars, note the supporting chitinoid rod; the small blood-vessel; the long ciliated cells of the pharyngeal epithelium on the inside and the shorter non-ciliated cells of the atrial epithelium on the outside.

Make a large 4- or 5-inch semi-diagrammatic figure, indicating by colored pencils or some other device, the epithelial structures derived from ectoderm and endoderm. If time permits, make an enlarged figure of a primary gill bar.

2. Through the mouth cavity. Draw.
3. Through the pharynx anterior to the liver. Draw.
4. Through the intestinal region in front of the atrial pore. Note, as peculiar features, the narrow body-cavity; the atrial cavity; the single dorsal aorta. Draw.
5. Through the tail region. Draw.

AN ELASMOBRANCH FISH

Squalus acanthias

The specimens for study are from the Atlantic coast and have preserved rather faithfully their natural external form, color, etc. The adults are about 3 feet long, so that most of our specimens are not sexually mature and the reproductive organs are not fully developed. Alternate specimens have the systemic arteries injected from the caudal artery with yellow or red injection-mass, and in a few cases the colored mass has run through into the veins and ventral aorta.

External Characters.—Note the division of the body into head, trunk and tail (that part of the body posterior to the cloacal opening); the color in the various parts; the scales—their size and direction in the various parts of the body; the paired pectoral and pelvic fins (in the male, the inner parts of the latter specialized to form the **claspers** for copulation); the two dorsal fins, each with a spine (a modified scale) at the anterior end; the caudal fin, with the axis of the tail bending dorsally in it; the mouth, with the scales over the jaws modified as teeth; the eyes (eyelids?); the olfactory organs in front of the mouth; the six pairs of gill-slits, the first pair

modified as the **spiracles** back of the eyes; the **cloacal opening** between the pelvic fins.

Make a quick drawing from the left side. — *Dorsal view*

The Skeleton.—The skeleton is purely **cartilaginous**. It is divisible into the **axial skeleton**, composed of the **vertebral column**, **skull** and the **visceral skeleton of the mouth**; and the **appendicular skeleton**, composed of the **skeleton of the fins**, and the **pectoral and pelvic girdles**. In the prepared skeletons of the Dog-fish or Ray, note the vertebral column composed of distinct **vertebræ**; the **notochord**, showing between the vertebræ and in the vertebræ as hour-glass-shaped structures; from the dorsal side of the vertebræ, the **neural arches** enclosing the spinal cord (best seen in transverse sections later); the **hæmal arches**, forming rib-like outgrowths in the region of the body-cavity and, in the tail, arching over the caudal blood-vessels (to be studied later in transverse sections). In the skull note as special features the **cranium** or brain-case between the orbits; the rounded **nasal capsules** anterior, and the **auditory capsules** posterior, to the orbits. Note the **visceral arches**, the first one modified to form the upper and lower **jaws**; the second forming the **hyoid arch**, of which the upper part suspends the jaws from the skull; the five **branchial arches**. Note the skeleton of the fins and the **pectoral and pelvic girdles**; in all the fins, the **fin rays**.

Internal Structure.—Make a ventral incision through the body-wall, forward to the pectoral girdle and backward to the posterior end of the cloacal opening, passing to one side of the latter. Make transverse incisions back of the pectoral fins and in front of the pelvic fins and pin out the flaps. Note the glistening **peritoneum**, lining the **body-cavity**, covering all of the organs within it, and forming the **mesentery** and other membranes which sling the various organs from the dorsal body-wall; the large two-lobed **liver**, with the **gall-bladder** under the right lobe; the wide **esophagus**; the J-shaped **stomach**; the **pylorus**, a constriction between stomach and **intestine**; the long **intestine**, with cross-lines along the larger

urine genital - gonads, kidneys, 2 long bands
dorsal *lateral* *ventral*

part, indicating the spiral valve within (to be studied later); the narrow **rectum**, the posterior part of the intestine; the **cloaca**, into which open the intestine and the **ducts** of the **urinary** and **reproductive systems**; the **pancreas**, in the angle between the stomach and intestine and dorsal to the lower part of the stomach; the dark, angular **spleen**; the **rectal gland** dorsal to the rectum. Trace the **bile duct** from the gall bladder alongside the hepatic portal vein, to enter the intestine a half-inch below the pylorus. *Fig. 2*

The Heart and Gills.—Remove the skin and muscles from the ventral side of the head, posterior to the mouth. Cut away the median inch of the pectoral girdle to expose the **pericardial cavity**, with the contained **heart**, and the **conus arteriosus** arising from it. With scissors in the gill-slits, cut away the ventral side of the gills of both sides. In the heart note the single thick-walled **ventricle**; the **sinus venosus** dorsal to it; the single **auricle**, dorsal to the ventricle and at its sides; the **conus arteriosus**, arising from the ventricle. Study the **gills**, noting their number, nature and relations; the **gill-arches**, supporting the gills, with **gill-rakers** extending into the mouth cavity.

Make a quick drawing of your whole specimen, ventral view, representing the organs of the body-cavity in place or only slightly displaced.

The Urinogenital System.—All parts of the reproductive systems are much undeveloped in these young specimens, especially the ducts. In either sex note the **kidneys**, a pair of dark, narrow organs dorsally along most of the length of the body-cavity; in the male, the **ureters** along the ventral side of the kidneys and opening into the cloaca; the **testes**, a pair of whitish, angular organs dorsal to the anterior end of the liver. In the female note the pair of **ovaries** dorsal to the anterior end of the liver; on either side, the **oviduct**, emptying into the cloaca and extending forward to the extreme anterior end of the body-cavity, where the two ducts converge on the ven-

tral side of the liver to open into the body-cavity by a single median slit-like opening. Cut away the posterior inch of the oviduct of one side and note the very small ureter, going to the cloaca.

Draw what you have made out of the urinogenital system of your specimen.



The Blood-Vascular System—General Statement.—The following general plan of the circulatory system of the dogfish should be kept in mind: 1, the single ventricle is the pumping organ and keeps the blood circulating throughout the whole body. 2, from the ventricle, only impure blood passes through the conus arteriosus and the ventral aorta and its branches to the capillaries of the gills, where it is oxygenated. 3, from the gills, the blood is gathered up into the dorsal aorta, which supplies all parts of the body with oxygenated blood, including oxygenated blood to the liver and kidneys. 4, the minute, invisible capillaries supply the connection between the very small arteries and veins of the systemic circulation; 5, blood from the tail passes forward through the kidneys, as the renal portal circulation, before entering the posterior cardinal veins on its way to the sinus venosus. 6, blood from the digestive tract, pancreas, and spleen passes through the liver as the hepatic portal circulation, and then enters the sinus venosus. 7, blood from all other parts of the body returns to the sinus venosus direct. 8, all of the blood of the body, therefore, returns directly or indirectly into the single sinus venosus, thence to the single auricle and single ventricle.

Now draw the heart, and add the various parts of the venous system as you study them, all from the left side. Make a ventral incision across the ventral side of the sinus venosus. Cut across the middle of the liver lobes and note the hepatic veins. Trace them forward through the hepatic sinuses into the sinus venosus. The sinus venosus extends laterally on either side into the precaval sinus, formed by the union of the

jugular or **anterior cardinal sinus** and the **posterior cardinal sinus** which arises from the kidneys. Insert a glass probe forwards into one of the anterior cardinals; and trace the posterior cardinals to their origin between the kidneys. The preaval sinuses also receive the **inferior jugular veins** from the ventral side of the head and the **lateral veins** from the sides of the body-wall.

Trace the hepatic portal vein as far as you can into its branches from the digestive tract, pancreas and spleen.

Complete your drawing of the heart and venous system.

The Arteries:—Cut away the muscles of the ventral side of the head. Be especially careful not to injure the **ventral aorta** and its branches, which are continuous anteriorly from the conus arteriosus. Trace the ventral aorta forward to where it divides into right and left halves. Trace the right half into the **first and second afferent branchial arteries**. Trace these along the gill arches to the gills as far as you can. About half way to its anterior branching the aorta gives off the **third afferent branchial artery**. Just next it, toward the heart, rather on the dorsal side, arises another trunk which gives rise to the **fourth and fifth afferent branchial arteries**.

Draw the heart and arteries as far as you have studied them and add the systemic arteries as you dissect them, all as seen from the left side.

Now cut through the angle of the mouth of the right side of your specimen and continue the cut back through the pharynx, gullet, and the body-wall a little beyond the heart. Carefully dissect away the membrane from the roof of the mouth. Note the **four pairs of efferent branchial arteries uniting to form the dorsal aorta**. From the first pair arise a pair of **carotid arteries** to the head.

Trace the dorsal aorta and its branches. Note the pair of **subclavian arteries** (to the front fins) arising just in front of the entrance of the fourth branchial arteries into the aorta;

the single large **cœliac** artery to the anterior part of the stomach and intestine, and to the liver and pancreas; the **anterior mesenteric**, to the lower part of the intestine; the **lieno-gastric** to the lower end of the stomach and to the spleen; the **inferior mesenteric** to the rectal gland; the pairs of small **renal arteries** to the kidneys (best seen by freeing one of the kidneys along its outer border from the dorsal wall near its posterior end); a pair of small **iliac arteries** to the pelvic fins; the continuation of the aorta as the caudal artery to the tail. Along the course of the aorta, note the pairs of small arteries to the trunk.

Complete your drawing of the arterial system.

Cut away a strip of the intestinal wall a half inch wide along its whole length, and make transverse incisions between several of the transverse lines of the intestine to expose the wide fold of the lining of the intestine known as the "**spiral valve**." Wash out and examine. Now remove the whole digestive tract, cut it open throughout its length and examine.

Make a **transverse section** of the tail just back of the cloacal opening. Note **spinal cord**, **vertebral column**, **caudal artery** and **caudal vein**, muscles, etc.

Draw the Section.

Cut off and throw away all of your specimen except the head, with two or three inches of the trunk.

The Nervous System and Sense Organs.—A number of dissected demonstration specimens are left out to guide you in this dissection. Remove the skin of the dorsal side of the head and above the eyes. Carefully cut away the dorsal cartilaginous wall of the brain-case and orbits and the massive ear capsules, posterior to the orbits. Be careful not to injure the white cord-like cranial nerves in the orbits and back of them.

In the exposed brain, note the five general regions of the vertebrate brain: 1, the **cerebral hemispheres (telencephalon)**; 2, the small 'tween-brain (**thalamencephalon**); 3, the **mid-brain (mesencephalon)**, showing the large **optic lobes** of the dorsal side; 4, the rather large **cerebellum**, the dorsal part of

the **metencephalon**; 5, the **medulla oblongata** (**myelencephalon**). Tear away the thin roof of the 'tween-brain to expose the **third ventricle**. Note large nerves running through the orbits dorsally (parts of the fifth and seventh cranial nerves); also, the **small fourth cranial nerve** arising on the dorsal side between the mid-brain and cerebellum. Carefully trace the fourth nerve forwards, and then outwards through the wall of the cranium to the superior oblique muscle of the eye-ball.

The Muscles of the Eyeball.—Now clear away the anterior and posterior walls of the right orbit, being careful not to injure any of the nerves and muscles. Cut through the skin on the ventral side of the eyeball to loosen it from the ventral side of the orbit. Study the six muscles of the eyeball, of which the **four rectus muscles** have their origin on the posterior wall of the orbit and the **two oblique muscles** on the anterior wall. Their insertions are on the eyeball as follows: 1, the **superior rectus** on the dorsal side; 2, the **inferior rectus** on the ventral side; 3, the **internal rectus** on the inner side; 4, the **external rectus** on the posterior side; 5, the **superior oblique** dorsally on the anterior wall of the eyeball; 6, the **inferior oblique** ventrally on the anterior wall of the eyeball.

The Cranial Nerves.—Study these on either side as follows: 1, The **olfactory**. Cut away the cartilage to expose the stalk from the fore-brain to the **olfactory bulb**, from which there run to the large nostril numerous small nerves which together constitute the **olfactory nerve**. 2, The **optic nerve** penetrating near the centre of the eyeball to supply the retina. 3, the **oculomotor**. It arises from the brain on the ventral side just in front of the origin of the rectus muscles. It quickly divides into three branches which are difficult to trace: A, to the internal rectus muscle; B, to the superior rectus muscle; C, to the inferior rectus and inferior oblique muscles. 4, already studied. 5, the **trigeminal**, the largest of the cranial nerves. (The 5th, 7th and 8th arise very close together from the medulla at its anterior end. The 5th immediately divides

into two branches. One has already been seen passing through the orbit; it supplies the dorsal side of the snout. The second branch runs posterior to the insertion of the rectus muscles and then forwards through the orbit under the eye-ball to the ventral side of the snout, and to the lower jaw). 7, the **facial**. One branch runs forward along with the upper branch of the 5th, as already noted. The main branch runs a tortuous path to muscles back of the spiracle. 8, the **auditory**, a very short nerve, goes immediately to the ear. 9, the **glosso-pharyngeal**, a slender nerve an eighth of an inch behind the 8th, going to the two sides of the first gill-cleft. 10, the **vagus** (difficult to trace fully), supplying nerves to the last four gill-clefts, the heart, and the stomach.

Draw the brain and nerves, so far as studied, and the eye-ball and its muscles, x4.

Remove the brain and examine it from the ventral side. Note **optic chiasma**—the crossing of the optic nerves; the **pituitary body**; the 6th pair of **cranial nerves**, small nerves from the medulla near the mid-line just posterior to the origins of the 5th and 7th nerves, and supplying the external rectus muscles.

Draw from the ventral side, x4.

THE COMMON LEOPARD FROG

Rana pipiens

Any of our species of larger frogs might be used for study. The leopard frog is found almost throughout the United States, is by far the most abundant in Minnesota, and is the most frequently used for laboratory work. Specimens for dissection are killed with chloroform several hours before they are to be used.

External Features.—Observe both a living and a dead specimen, comparing all the while with your own body, what you find in the frog. Note the smooth, soft **moist skin**—its

coloration in all parts of the body; the division of the body into head, trunk, and limbs; the external openings—nostrils, mouth, and cloacal opening or anus; eyes (touch one in the living specimen), eyelids, tympanic membrane or drum-head of the ear; in the fore limb, arm, forearm, hand; in the hind limb, thigh, leg, foot; in both limbs, the digits—their number and nature.

The male frog is distinguished externally from the female by a swollen, rough cushion on the innermost digit of the hand. Carefully observe the respiratory movements, and make note of the events that take place.

Pin your dead specimen out in the pan, dorsal side up, with the fore-limbs out at the sides; the hind-limbs obliquely out at the sides; and all of the digits spread out so as to show in the dorsal view. Draw accurately, natural size, naming all of the parts you have observed.

In the dead specimen study the features of the mouth cavity, clearing the cavity free of mucus if necessary. Note the maxillary teeth on the margin of the upper jaw and the vomerine teeth on the palate; the tongue—its character and mode of attachment; the internal nasal openings; in the floor of the mouth, the slit-like glottis, the opening into the trachea; the opening into the esophagus; the Eustachian recesses at the sides of the mouth, leading to the drums of the ears.

Draw the features of the mouth cavity, representing the mouth as wide open, x2.

The Skeleton—Preparation of the Skeleton.—Remove the skin, muscles and all other soft parts from a freshly-killed frog. Be careful not to destroy the delicate cartilages at both ends of the sternum on the ventral side of the breast, and of the scapulas or shoulder-blades on the dorsal side. The fore-limbs and the parts to which they are attached should be separated from the rest of the skeleton and should be cleaned separately.

After removal of all soft parts so far as possible, dip the skeleton into boiling water for one or two seconds. Complete

the cleaning, dipping into hot water again when necessary. Alternate students should preserve their skeletons dry and moist.

Viewing the skeleton as a whole, note its division into the **axial skeleton**, consisting of the **skull** and **vertebral column**; and the **appendicular skeleton**, consisting of the **skeleton** of the **fore** and **hind-limbs**, and the **pectoral** and **pelvic girdles** to which they are attached. What is the relation of these girdles to the axial skeleton?

The Vertebral Column.—The column consists of nine **vertebræ** and the **urostyle**. Study one of the isolated middle **vertebræ**. It forms a **neural ring** enclosing the **neural canal** which in life contains the spinal cord. Note, as parts of the vertebra, the massive body or **centrum** on the ventral side; the **neural arch** arising from it; the pair of **transverse processes** extending laterally; the **anterior** and **posterior articular processes** at the two ends; the single median dorsal spinous process.

Make simple drawings from end and side views, x 8 or 12.

Compare the first vertebra or **atlas** and the last or **sacrum** with the middle vertebra and note the differences. Draw these two if you have time.

Draw the whole vertebral column from the dorsal view.

The Skull.—Use both a dry and a moist skull for study. Note its division into the **cranium**, enclosing the brain and more or less completely enclosing the **olfactory** and **auditory capsules**; and a **facial portion**, the skeleton of that portion of the head concerned with the securing of food. Note the **foramen magnum** at the posterior end for the connection of the brain and spinal cord; at its sides, the pair of convex **occipital condyles** of the **exoccipital** bones, articulating in life in the concave, anterior articular surfaces of the atlas; the **prootic** bones, forming the roof and anterior wall of the auditory capsule; the irregular T-shaped **squamosals**, extending ventrally and slightly posteriorly to suspend the lower jaw from the cranium; the pair of large, flat **fronto-parietals**, on the dorsal

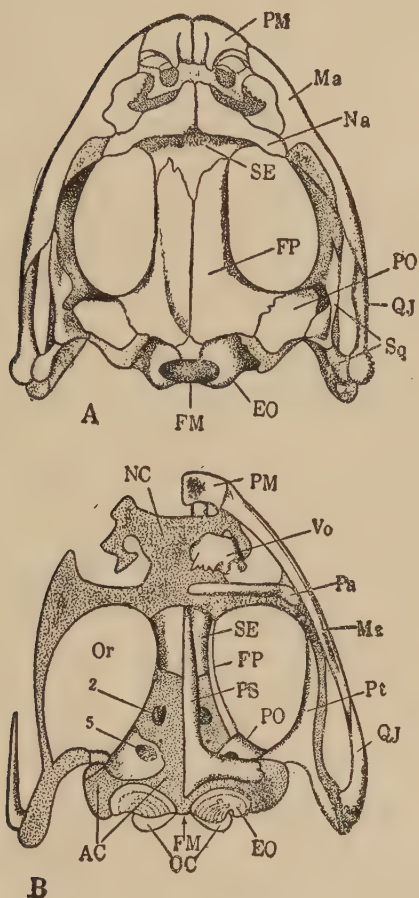


Fig. 15—A. and B.—Dorsal and ventral views of the skull of frog, x2. In B, the superficial investing bones of the right side are removed. (A from Wiedersheim; B from Hertwig's Zoology, after Wiedersheim.)

AC, auditory capsule; **EO**, ex-occipital bone; **FM**, foramen magnum; **FP**, Fronto-parietal; **Ma**, maxillary; **Na**, nasal; **NC**, nasal capsule; **OC**, occipital condyles of the ex-occipital bones; **Or**, orbit of the eye; **Pa**, palatine; **PO**, prootic; **PM**, premaxilla; **PS**, parasphenoid; **Pt**, pterygoid; **QJ**, quadrato-jugal; **SE**, sphenethmoid; **Sq**, squamosal; **Vo**, vomer; **2, 5**, foramina for the exit of the second and fifth cranial nerves from the skull.

side between the orbits; the **sphenethmoid**, a ring of bone under the anterior end of the fronto-parietals; the **nasals**, a pair of small scale-like bones anterior and lateral to the sphenethmoid; the **premaxillæ**, a pair of smaller bones in the upper jaw next to the mid-line and, with the larger **maxillæ**, bearing the maxillary teeth; the small **quadrato-jugals**, between the maxillæ and squamosals.

Draw from dorsal view, x4.

On the ventral side note, in addition to some of the above that are seen from the ventral side, the large median, dagger-shaped **parasphenoid**; the **palatines**, a pair of small splint-like bones extending transversely on the anterior wall of the orbit; the **vomers**, bearing the vomerine teeth; the tri-radiate **pterygoids**. In each half of the lower jaw note the core of **Meckel's cartilage**, overlaid on the inside by the **splénial** bone and on the outside by the **dentary**, and ossified near the mid-line to form the **predentary**.

Draw the lower jaw from one side and the rest of the skull from the ventral view, x4.

Before any bones have been formed in the skull of the tadpole, most of it has been mapped out in **cartilage**. In the adult frog, certain of the bones, the "**cartilage bones**," have been developed by the formation of bone in the original cartilaginous **cranium**; others, the **investing bones**, have been formed in the **membrane surrounding** the original skull. In a skull softened by careful boiling remove the investing bones—the fronto-parietals, squamosals, nasals, premaxillæ, maxillæ, vomers, parasphenoids, splénials and dentaries. The skull will be left in the condition shown at the left of B in fig. 15. Study the skull as it now remains, observing that there is left an almost completely closed brain case. Note the **fontanelles**, one large hole and two smaller ones on the dorsal side where the cartilaginous skull is incomplete; the **foramina**, a series of smaller holes on the ventral side which give exit to certain of the cranial nerves.

Draw a dorsal view, x4.

The Appendicular Skeleton—The Fore-limb and Shoulder Girdle, and the Sternum.—Study the sternum, the shoulder girdle and the skeleton of the fore-limb. The median sternum includes in succession, the following parts: the **episternum**, a delicate, rounded cartilage; the **omosternum** and **metasternum**, two bony rods; the cartilaginous **bilobed xiphisternum**, at the posterior end. Lateral to the sternum on either side are the smaller **clavicle** anteriorly and the larger **coracoid** posteriorly. Lateral to these and arching dorsally around the vertebral column is the **scapula**, the dorsal part a thin plate of cartilage. Study the **glenoid fossa** in which the head of the **humerus** articulates. This joint is a typical **ball-and-socket joint**.

Draw the sternum and girdle, ventral view, representing the girdle as somewhat flattened, x2.

In the skeleton of the fore-limb, note **humerus**; **radio-ulna**, **radius** and **ulna** fused; the **carpal** bones of the wrist (you will hardly make out their relations in detail); the long **metacarpal** bones of the hand; the **phalangeal** bones of the digits.

Draw the skeleton of the fore-limb, x2.

The Hind-limb and Pelvic Girdle.—The pelvis is made up of two halves (the **innominate bones**) fused together posteriorly on the mid-line, and bears on each side an **acetabulum**, the large socket in which the head of the **femur** articulates. As viewed from the side, note that each innominate bone consists of three parts, all of which help to form the acetabulum: 1, the long **ilium**, articulating in front with the vertebral column; 2, the **pubis**, a small triangular cartilaginous part on the ventral side; 3, the **ischium**, the posterior part.

Draw from one side, x2.

In the skeleton of the hind-limb note the **femur** articulating with the innominate at the **acetabulum**; the **tibio-fibula**, **tibia** and **fibula** fused; the **tarsal** (of which two are greatly enlarged) bones of the ankle; the long **metatarsal** bones of the foot; the **phalangeal** bones of the digits.

Draw the skeleton of the hind-limb, x2.

The Muscular System of the Frog.—One laboratory period will be given to a study of the frog's muscles, both for a knowledge of the nature and arrangement of muscles, and for the practice in dissection.

The **voluntary** muscles, controlled by the will, are well-defined organs of the body. The **involuntary** muscles, under no direct control of the will, are arranged usually as sheets of muscles, as in the digestive tract; or in masses, as in the heart. This dissection deals with the voluntary muscles.

Each voluntary muscle is an organ and, in the majority of cases, is attached to bones at both ends. Contraction of muscles usually causes movements of parts of the skeleton, resulting in motion of the body in part or as a whole.

A typical muscle is usually more or less spindle-shaped, with a **belly** of muscle tissue (the contractile part), from which sharply defined **tendons** extend to the bones for attachment.

In most muscles of the body, one end (the **origin**) remains more fixed during contraction; the other (the **insertion**) is more movable.

In your dissection reference should be made constantly to the skeleton to understand better the attachments of the muscles.

Remove the skin from a frog that has been preserved in alcohol. Keep the specimen moist by immersing it in water from time to time. Free the muscles along their length by means of a blunt needle or fine-pointed forceps.

A Typical Muscle.—The **gastrocnemius** or calf muscle of the lower leg will give a sharp idea of the nature of voluntary muscles in general. Free it along its middle so as to show its two tendons with their attachments. The origin is mostly upon the inside of the **femur**, partly upon the tendon of the triceps muscle; the insertion is through the **tendon of Achilles** upon certain tendons under the foot. Its contraction causes extension of the foot.

Now, using the figures freely as a guide, dissect, identify, and study the origins and insertions of as many muscles as

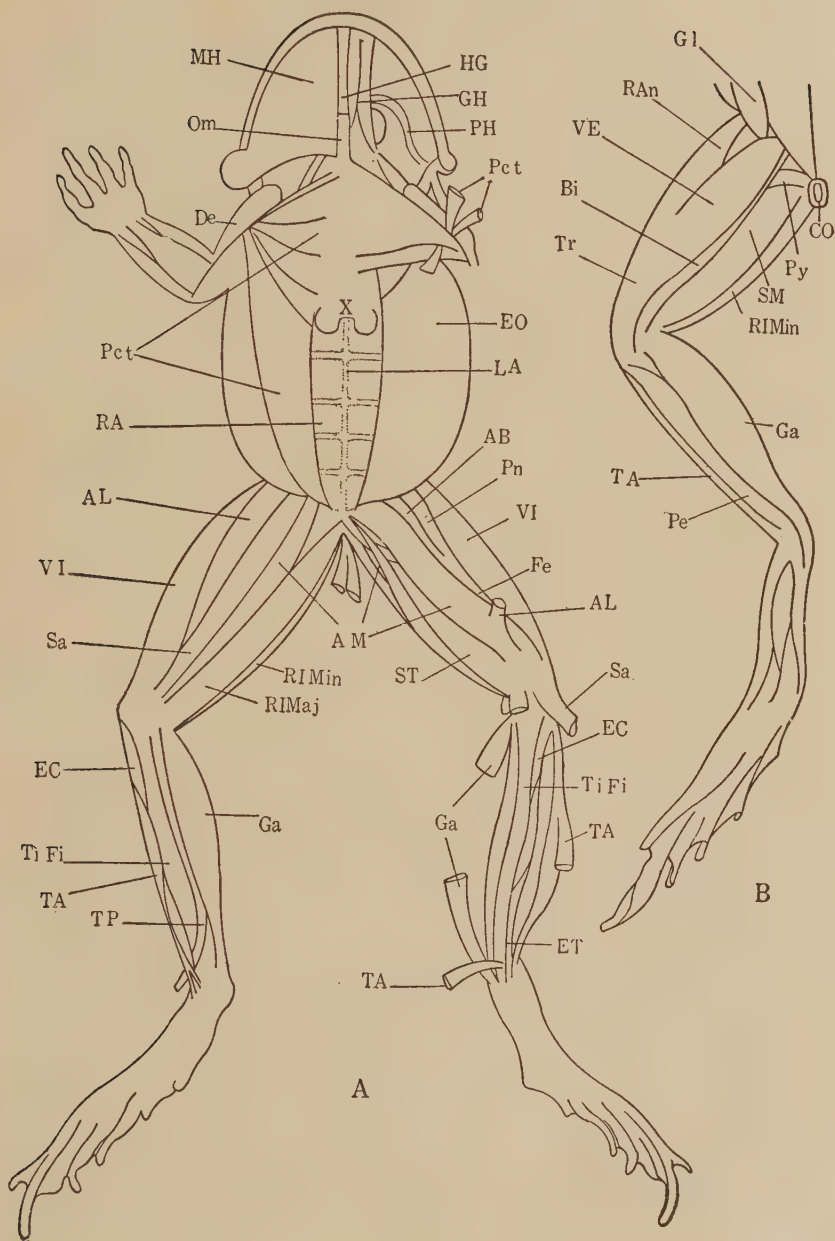


Fig. 16 A.—Dissection of the muscles of the frog from the ventral side. Several of the superficial muscles of the left side have been cut and reflected so as to show the deeper muscles. (After Parker and Haswell.)

B.—Dissection of the superficial muscles of the frog's leg, dorsal view. (After Marshall.)

AB, adductor brevis; **AL**, adductor longus; **AM**, adductor magnus; **Bi**, biceps; **CO**, cloacal opening; **De**, deltoid; **EC**, extensor cruris; **EO**, external oblique; **ET**, extensor tarsi; **Fe**, femur; **Ga**, gastrocnemius; **GH**, genio-hyoid; **Gl**, gluteus; **HG**, hyoglossus; **LA**, linea alba; **MH**, mylo-hyoid; **OM**, omosternum; **Pct**, pectoralis; **Pe**, peroneus; **PH**, posterior horn of hyoid apparatus; **Pn**, pectineus; **Py**, pyriformis; **RA**, rectus abdominis; **RAn**, rectus anticus femoris; **RIMaj**, rectus internus major; **RIMin**, rectus internus minor; **Sa**, sartorius; **SM**, semi-membranosus; **ST**, semi-tendinosus; **TA**, tibialis anticus; **TiFi**, tibio-fibula; **TP**, tibialis posticus; **Tr**, triceps; **VE**, vastus externus; **VI**, vastus internus; **X**, xiphisternum.

time permits. Dissect them in the following order: the ventral side of the hind-limb; the dorsal side of the hind-limb; the muscles on the ventral side of the trunk.

Make a table to show what you find, similar to this as an example:

Name of Muscle.	Origin.	Insertion.
Sartorius.	Pelvis.	Head of Tibia.

Draw and name the muscles of both sides of the hind-limb.

Internal Structure.—In all dissections, cut the blood-vessels as little as possible. Handle the organs only with smooth, blunt objects. Guard against prodding them with sharp instruments, which causes the blood to ooze out and so obscures the dissection. Keep the specimen covered all the while with clear water.

Fasten your specimen down, ventral side up, with pins through the tip of the snout and all the limbs. Raise the skin from the body with forceps and cut through it with scissors along the mid-line from the pelvis to the tip of the lower jaw, noting the large lymph space between the skin and muscles. Free the skin from the breast by cutting the muscles which attach it in this region. Make cross incisions of the skin and pin the flaps out at the sides, being careful not to cut the large cutaneous veins of the skin on the sides of the body. Note the

very thick, firm **body-wall** between the fore-limbs, composed of muscles and bones; the thin wall over the **abdomen**, made up of several very thin muscles; the **abdominal vein**, in the mid-ventral line between the muscles of the two sides.

Lift up the muscles of the abdomen away from the inter-

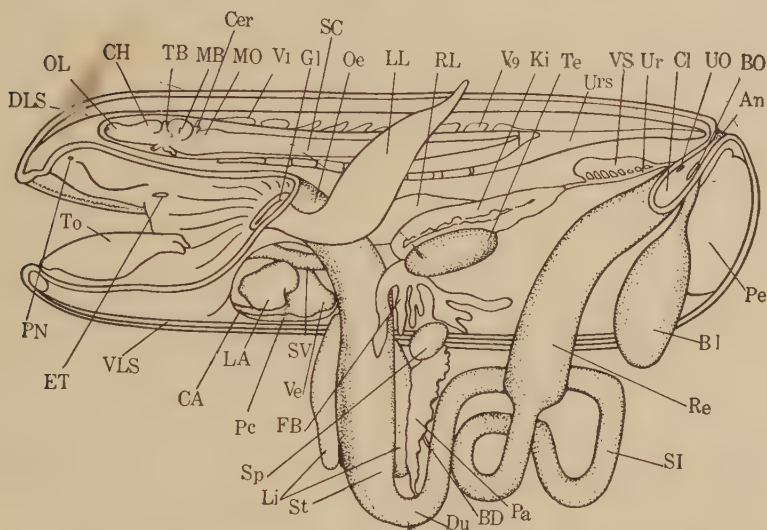


Fig. 17.—Dissection of a male frog from the left side. The skull and vertebral column are represented as removed to the mid-line to show the brain and spinal cord. The wall of the mouth is shown removed to near the mid-line, so as to show the glottis and the opening into the esophagus; which are median. The pericardium is removed on the left side to show the heart. The left wall of the cloaca is removed posteriorly to show the openings of the ureter and bladder. The viscera are somewhat displaced from their natural positions. (From Parker and Haswell.)

An, anus; **BD**, bile duct; **Bl**, urinary bladder; **BO**, opening of bladder into cloaca; **CA**, conus arteriosus; **Cer**, cerebellum; **CH**, cerebral hemisphere; **Cl**, cloaca; **DLS**, dorsal lymph space; **Du**, duodenum; **ET**, Eustachian tube; **FB**, fat bodies; **Gl**, glottis; **Ki**, kidney; **LA**, left auricle; **Li**, liver; **LL**, left lung; **MB**, midbrain; **MO**, medulla oblongata; **Oe**, esophagus; **OL**, olfactory lobe; **Pa**, pancreas; **PC**, pericardial cavity; **Pe**, pelvis; **PN**, posterior naris (internal nasal opening); **Re**, rectum; **RL**, right lung; **SC**, spinal cord; **SI**, small intestine; **Sp**, spleen; **St**, stomach; **SV**, sinus venosus; **TB**, 'tween-brain; **Te**, testis; **To**, tongue; **Ur**, ureter; **Urs**, urostyle; **V1**, **V9**, first and ninth vertebræ; **Ve**, ventricle; **VLS**, ventral lymph space; **VS**, seminal vesicle.

nal organs and cut through the body-wall (including the sternum) slightly to one side of the mid-line from the pelvis to the posterior end of the lower jaw, being careful not to injure the internal organs. Observe the abdominal vein passing dorsally to the liver posterior to the heart. Cutting across the body-wall just in front of this vein, remove a middle section of the sternum about a half inch wide. Make transverse incisions of the body-wall at about the middle of the abdomen and pin out the flaps. Pull the fore-limbs somewhat apart and fasten with pins. Cover your specimen with clear water.

Study the internal structures as now exposed in their natural positions and relations. Note the body-cavity, filled with the organs of the various systems; the peritoneum, the smooth, glistening membrane lining the body-cavity, covering all of the organs within it, and forming the membranes which sling certain of these organs from the dorsal body-wall. Note the heart, lying within the delicate, membranous pericardium, which forms a closed sac; the liver, consisting of right and left lobes, the latter divided into two parts; the gall-bladder, a small sac under the right lobe of the liver; the lungs, a pair of sacs, small or large, depending on their degree of inflation; the long thick-walled stomach; the narrow, thin-walled, coiled small intestine; the pylorus, the constriction at the junction of the stomach and intestine; the wider large intestine (rectum) continued posteriorly into the ^{lower} cloaca, which opens through the cloacal opening or anus to the outside; the bilobed urinary bladder (usually collapsed); the large glove-shaped, yellow fat-bodies. In the female specimen, note the pair of very large ovaries, containing the large white-and-black ova; the oviducts, a pair of light, long, coiled tubes at the sides. In the male, the small yellow testes.

Make a quick drawing of your whole specimen, showing the organs in their natural positions and relations.

Inflate the lungs by means of a blow-pipe through the glottis; if your specimen is a female, remove the left ovary;

turn the liver forward so as to expose the **esophagus** as it enters the stomach; pass a glass probe from mouth to stomach. Now trace the digestive tract throughout its whole length, noting the membranous **mesentery** which slings it from the dorsal body-wall. Note the **pancreas**, a long, thin, pinkish body lying between the stomach and the first part of the intestine; the **spleen**, a small, spherical dark-red body lying in the mesentery; the long, deep-red **kidneys**, *- adrenal body*

Make a large drawing of your whole dissection, representing the stomach and intestine as if pulled to your right side. ~~Omit~~ the urinary and reproductive systems from this drawing. Also, make a separate drawing of the whole digestive tube, from the mouth to the anus, natural size.

P. major
The Blood-Vascular System—General Statement.—The following general plan of the circulatory system of the frog should be kept in mind during your study: 1, the single ventricle of the heart is the sole pumping organ and keeps the blood circulating throughout the whole body. 2, from the ventricle a single system of arteries carries blood to all parts of the body, including oxygenated blood to the kidneys and liver. 3, the minute, invisible capillaries furnish the connection between the very small arteries and veins. 4, blood from all parts of the body except the lungs is returned to the sinus venosus, thence to the right auricle of the heart as follows: a, from the head and fore-limbs to the heart direct through a pair of large precaval veins; b, blood from the hind-limbs partly passes first to the kidneys as the **renal portal circulation** and thence to the postcava and heart; partly flows forward through the abdominal vein to join the hepatic portal vein to the liver; c, from the stomach, intestine, spleen and pancreas, blood is carried through the hepatic portal vein first to the liver as the **hepatic portal circulation** and thence to the heart through the postcaval vein. 5, blood from the lungs is returned direct to the left auricle through the pulmonary veins. 6, blood from both auricles returns to the single ventricle, completing the whole pathway of the circulation.

be similar to that of C.C. ...

Pin out a freshly killed frog under water, which must be changed as often as it becomes clouded. Use great care now and subsequently not to cut any of the blood-vessels large enough to be seen. When tracing a vessel, free it along its course, being careful not to injure the vessel. Expose the internal structures as before, dissecting the abdominal vein free from the ventral wall of the abdomen. Tie two ligatures a quarter inch apart around it near the middle and cut across the vein between them. Make cross-incisions in the body-wall and pin out the flaps. If your specimen is a female, very carefully remove the ovary and oviduct of the frog's left side. Pull the fore-limbs somewhat apart and pin out.

The Heart.—With fine forceps, grasp the very thin pericardium, lift it up and dissect off with extreme care from the ventral side of the heart. Note the thin-walled, dark-red base of the heart, consisting of **right** and **left auricles**; the thicker-walled, pinkish **ventricle** forming the apex; the **conus arteriosus** arising from the ventricle and dividing into a **right** and a **left aortic arch**. Turn the ventricle forward and note the dark, thin-walled **sinus venosus** dorsal to the ventricle. If the heart is still pulsating in your specimen, observe the **sequence** in the heartbeat of the different parts.

The Venous System.—Observe the pair of large **right** and **left precaval veins** entering the sinus venosus from the anterior part of the body. Each is formed by the union of the three following veins:

- 1, the **external jugular** from the ventral side of the head.
- 2, the **innominate**, formed by the union of the **internal jugular** at the angle of the lower jaw from the deeper parts of the head, and the **subscapular** from the shoulder.
- 3, the **axillary**, formed by the union of the **subclavian** from the arm and the **cutaneous** from the skin and lateral muscles.

Begin your drawing of the heart and venous system, and add the other parts as you dissect them, x2. Draw only the

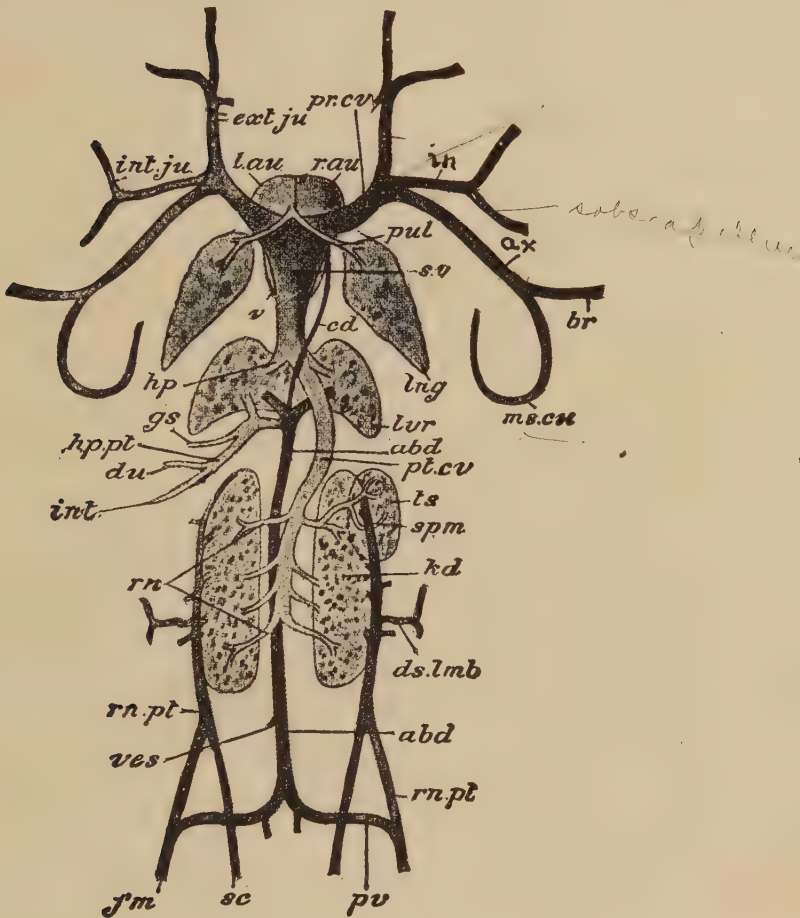


Fig. 18—Venous system of the frog, dorsal view, abd, abdominal vein; ax, axillary; br, brachial (subclavian) vein; cd, cardiac vein; ds. lmb, dorso-lumbar vein; du, duodenal; ext. ju. external jugular; fm, femoral; gs, gastric; hp, hepatic; hp. pt, hepatic portal; in, innominate; int, intestinal; int. ju, internal jugular; kd, kidney; l. au, left auricle; lng, right lung; lvr, liver; ms. cu, musculo-cutaneous; pr. cv, prevacal; pt. cv, post caval; pul, pulmonary; pv, pelvic; r. au, right auricle; rn, renal; rn. pt, renal portal; sc, sciatic; spm, spermatic; s. v. sinus venosus; ts, testis; ves, vesical vein. (From Parker and Haswell.)

vascular system, omitting all other parts, except diagrams of the liver, digestive tube, and kidneys.

Lift up the posterior end of the abdominal vein by means of the ligature and note that it is formed by the union of a pair of converging **pelvic veins**. Lift up the anterior end and note that it divides into two **afferent hepatic veins** which enter the two lobes of the liver.

The **hepatic portal system** is difficult to study in detail. Turn forward the liver and note the **hepatic portal vein**, passing forwards through the pancreas. It is made up of branches from the stomach, intestine, spleen and pancreas; passes through the pancreas; give off branches to the left lobe of the liver; and then passes forwards to join the anterior abdominal where the latter divides into the two afferent hepatic veins.

Turn the alimentary canal to the frog's right side so as to expose the kidneys, and study the **renal portal system** of the left side. Tear away the tissues and expose the vessels so far as necessary. Note the **renal portal vein** skirting the kidney on its outer border and breaking up into the afferent renal veins which enter the kidney. Trace the renal portal posteriorly, noting that it arises from the **femoral vein** on the outer side of the thigh, but also receives the **sciatic vein** from the dorsal side of the thigh. The femoral vein of either side is thus seen to divide into a renal portal which runs forward to enter the kidney along its outer side, and a pelvic which unites with its fellow to form the abdominal. Trace the femoral posteriorly along the outer border of the thigh.

Note the formation of the **postcava (inferior vena cava)**, between the kidneys, by the union of the **efferent renal veins** which leave the kidneys from their inner borders; that it receives the **genital veins** from the reproductive glands; passes forward through the liver and receives the short, wide **hepatic veins** from the liver, and then enters the sinus venosus.

If you have a large specimen and time permits, trace the

pair of pulmonary veins from the roots of the lungs to unite and enter the left auricle.

Finish your drawing of the heart and venous system.

The Arterial System.—The two sides of the arterial system are alike. It will be better to trace it out on the left side, so as to leave the right side uninjured for the study of the urinogenital system later. In tracing the arteries you should follow them out away from the heart, carefully tearing away the tissues, including the veins, wherever necessary.

The conus arteriosus has already been observed to divide into a right and a left aortic arch. Trace the left aortic arch, noting its division into three trunks:

1, the anterior or carotid trunk, which divides into the lingual artery to the tongue and the carotid to the deeper parts of the head.

2, the middle or systemic trunk, which arches dorsally and gives off the vertebral artery to the body-wall adjacent, and the subclavian to the fore-limb. It then passes posteriorly and unites with its fellow of the opposite side to form the dorsal aorta. The dorsal aorta gives rise to the large celiaco-mesenteric to the stomach, liver, intestine, and spleen; several pairs of renal arteries to the kidneys; the genital arteries, usually coming off from the renal, to the reproductive organs; the very small inferior mesenteric artery to the large intestine. The aorta then divides into the pair of common iliac arteries, going to the hind-limbs.

3, the posterior or pulmocutaneous trunk, dividing into a pulmonary artery going to the lung and the cutaneous to the skin.

Draw the heart and arterial system, x2.

If you have time, the circulation of the blood may be studied in the web of the frog's foot.

Urinogenital Organs.—Very carefully remove the liver, stomach, and small intestine, so as to leave the urinary and reproductive systems. With heavy scissors remove an eighth

inch wide of the pelvis of the mid-ventral side, being very careful not to injure the bladder and cloaca. Pull the two legs apart and pin out so as to show the cloaca and parts in relation to it. Cover with water.

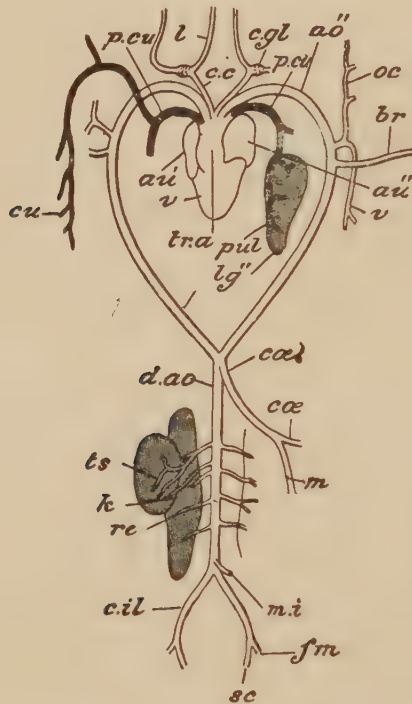


Fig. 19—Arterial system of the frog, ventral view. *ao''*, systemic trunk; *au'*, right auricle; *au''*, left auricle; *br*, brachial (subclavian) artery; *c.c.*, carotid; *c. gl.*, carotid gland; *c. il.*, common iliac; *coel*, celiac; *coel*, celiacomesenteric; *cu*, cutaneous; *d. ao*, dorsal aorta; *fm*, femoral; *k*, kidney; *l*, lingual; *lg''*, left lung; *m.*, anterior mesenteric; *m. i*, posterior mesenteric; *oc*, occipital; *p. cu*, pulmocutaneous; *re*, renal; *sc*, sciatic; *tr. a.*, truncus arteriosus; *ts*, testis; *v*, vertebral. (From Holmes, after Howes.)

Again go over the organs of the urinogenital systems so far as studied previously on page 110. In either sex, note the pair of reddish-brown **kidneys** on the dorsal side, each with a yellow streak, the **adrenal body**, on its ventral side; the

large, usually collapsed **urinary bladder** which empties into the cloaca ventrally.

In the male note, on either side, the very small **vasa efferentia**, tubes passing from the **testis** into the kidney; the **urinogenital duct** (which serves both as **vas deferens** to convey the seminal fluid, and as **ureter** to convey the urine), leaving the outer border of the kidney to pass to the **cloaca**; the **rudimentary oviduct**, extending forwards alongside the kidney as a conspicuous structure.

In the female, study the much coiled **oviduct** on either side. Anteriorly it begins as a **funnel-shaped opening** dorsal to the root of the lungs, leading from the body-cavity; posteriorly it empties into the dorsal side of the cloaca. Note the **ureter**, from the outer border of the kidney to the cloaca.

Dissect open the cloaca from one side to show the openings into it of the bladder and of the urinogenital duct of the male; or of the bladder, oviduct, and ureter of the female.

Draw the urinary and reproductive systems (only) of your specimen, ventral view. If your specimen is a female, represent the ovary on one side and the oviduct on the other.

The Nervous System—General Statement.—The nervous system of vertebrates consists of 1, the **central nervous system**, composed of the **five-parted brain** within the skull and the **spinal cord** in the vertebral column; 2, the **peripheral nervous system**, of which the **cranial nerves** from the brain and the **spinal nerves** from the spinal cord (ten pairs of each in the frog) are the most conspicuous parts. The essential nature and arrangement of the spinal nerves is well shown on the ventral side of the vertebral column.

The specimens for study have been first hardened to make the nervous tissues firm; and then treated with nitric acid to remove the hard calcareous matter of the skeleton, to facilitate the dissection. A number of demonstration dissections of the nervous system have been left in various places in the laboratory, to guide you in this dissection.

Remove the skin from the whole animal. Expose the brain and spinal cord by removing the roof of the skull and vertebral column with scissors. Begin by snipping through the cartilage of the anterior part of the skull; and then through the roof of the two sides alternately.

In the exposed **brain**, note the five regions: 1, the **cerebral hemispheres (telencephalon)**, with the anterior part continued forward as the **olfactory lobes**, from which the **olfactory nerves** arise to pass to the nose; 2, the small 'tween-brain (**thalamencephalon**), with the pair of large **optic nerves** to the eye on the ventral side; 3, the **mid-brain (mesencephalon)**, of which the rounded **optic lobes** are the prominent features of the dorsal side; 4, the very small **cerebellum (metencephalon)**; 5, the **medulla oblongata (myelencephalon)**, which is continued into the **spinal cord**; on the dorsal side of the medulla, the triangular **fourth ventricle**.

Note the ten pairs of **spinal nerves**, of which the 2nd, and the 7th, 8th, and 9th are especially enlarged. Why? Observe the origin of one of these larger spinal nerves from **dorsal and ventral roots**; their union to form the nerve; the **spinal ganglion** as a swelling on the dorsal root just before its union with the ventral root. Note the interconnections between the 7th, 8th, and 9th, forming the **sacral plexus**. Trace the large nerves into the hind-limb.

Draw the dorsal view of the central nervous system, and the nerves arising from it so far as you have studied them, x4 or 6. Pay special attention to size and proportions of the various parts of the nervous system.

Note the entrance of the large **optic nerve** into the eye-ball. Cut across the olfactory and optic nerves. Turn the brain back, cutting the various cranial nerves of the ventral side close to the skull so far as necessary to remove the brain and part of the spinal cord. On the ventral side of the brain note the optic nerves, arising from the **optic chiasma** which is formed by the union of the **optic tracts** emerging from the optic lobes; the **pituitary body**, a small bi-lobed flap extending

posteriorly from the 'tween-brain. Referring to the figure, identify as many of the cranial nerves as you can.

Draw the brain from the ventral side, x6.

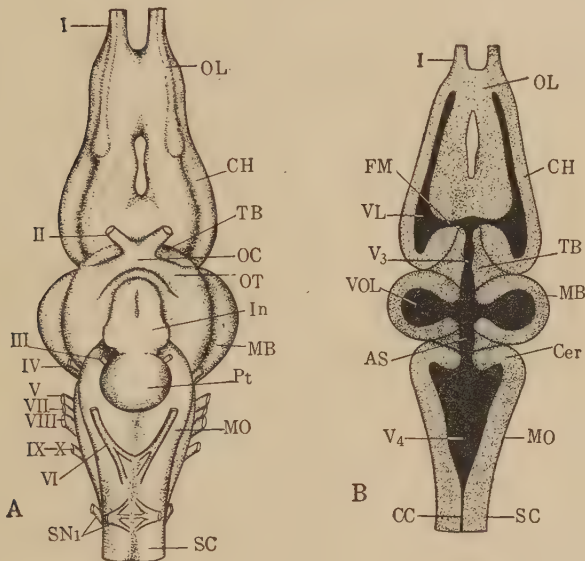


Fig. 20 A.—Brain of frog, ventral view. x6. (From Ziegler's model of the frog's brain.)

B.—Horizontal section of the frog's brain, to show the general arrangement of the parts and the ventricles of the brain. (After Ecker.)

AS, aqueduct of Sylvius between the third and fourth ventricles; CC, central canal of the spinal cord; Cer, cerebellum; CH, cerebral hemispheres; FM, left foramen of Monro, connecting the lateral ventricle of the hemisphere with the third ventricle; In, infundibulum; MB, mid-brain; MO, medulla oblongata; OC, optic chiasma; OL, olfactory lobe; OT, optic tract; Pt, pituitary body; SC, spinal cord; SN1, first spinal nerve; TB, 'tween-brain; VL, lateral ventricles of the hemispheres (first and second ventricles); VOL, ventricles of the optic lobes; V3, third ventricle; V4, fourth ventricle. The Roman numerals I-X refer to the paired cranial nerves as follows: I, olfactory; II, optic; III, oculomotor; IV, trochlear; V, trigeminal; VI, abducens; VII, facial; VIII, auditory; IX, glossopharyngeal; X, vagus or pneumogastric.

ANATOMY OF THE PIG FETUS

The pig belongs to the mammalian order Artiodactyla, or even-toed ungulates, which also includes cattle, sheep, camels, etc. The first digit of both fore and hind limbs has been lost and the 2nd and 5th are reduced, but functional. As in ungulates in general, the pig walks on the tips of its toes.

The period of gestation in the pig is about 112 days. The number of young in a litter may run up to 18, but the average number is about 8. The unborn animal is called a fetus. The pig at birth is about a foot long. The following are estimates for the approximate ages of the various sizes in millimeters, indicated: 11mm., 21 days; 17 mm., 35 days; 28 mm., 49 days; 40 mm., 56 days; 80 mm., 75 days; 150 mm., 85 days; 220 mm., 100 days; 300 mm., full term, 112—114 days.

The specimens for study were removed from the uterus of the mother and, in most cases, show a part of the **umbilical cord** still attached to the abdomen. The main systems and organs are mapped out early in embryonic life and a fetus two inches long shows the essential general plan of the adult. Specimens six inches or more in length furnish very excellent material for the study of the general structural features of a mammal. The cerebral hemispheres are less convoluted than in the adult; the reproductive organs have been formed but are small; the eyelids have been formed but are sealed together. In the main the anatomy is well shown. In following the directions, right and left apply to the right and left sides of the fetus.

The External Features. Observe these and compare with your own body and with the frog. Note, as special features, the **umbilical cord**; the **umbilicus**, the attachment of the umbilical cord to the body wall; the **anus** under the tail; the **urinogenital opening** of the female ventral to the anus, and of the male just posterior to the umbilicus; in the male the **scrotum**, a sac under the anus which, in the adult contains the

testes; the nipples in either sex—number and arrangement: the eyes, with sealed eyelids.

Draw from left side and label all parts, x1.

General Internal Anatomy. Remove the ventral third of the body-wall from the umbilicus to the base of the neck, so as to expose the pleural and peritoneal cavities and their contents. Note the umbilical vein passing forward to the liver. Cut through the body-wall posteriorly on both sides of the umbilicus, and cut across the umbilical vein to enable you to turn the middle strip of the body-wall backward. Carefully remove the skin of the ventral side of the neck to the posterior angles of the lower jaws, and of the left side of the head to the base of the ear. Also remove the muscles on the ventral side of the larynx and trachea. Now note the white thymus in front of the heart and extending on either side of the trachea and larynx to the base of the ear; the rounded, compact, light submaxillary gland at the angle of the lower jaw; the pair of dark thyroid glands, a half inch long, fused together, lying in the midline against the trachea at the base of the neck.

Note the diaphragm consisting of a central tendon and of muscles attached to the surrounding body-wall. The body-cavity is divided by the diaphragm into pleural and peritoneal cavities. In the pleural cavity note: pleura, the smooth lining of the cavity and covering all of the organs; the heart, surrounded by the pericardium and consisting of right and left auricles, and right and left ventricles; the left lung consisting of three lobes; the right lung consisting of four lobes, the last posterior to the heart.

In the peritoneal cavity note: peritoneum, the smooth lining of the cavity and covering its organs; the liver, consisting of left lateral, left central, right central, and right lateral lobes; the gall-bladder, under the liver; the umbilical vein, passing forward into the liver; the stomach, with the esophagus entering its cardiac portion and the intestine leaving its pyloric portion; the pylorus, the junction of stomach and duodenum (the first part of the small intestine); the long dark spleen on

6 ft. nipples in this animal
but does

Liver
gall b
umbilical
esophagus
spleen

60
5

12

the left side; the light **pancreas**, between the stomach and intestine; the many coils of the **small intestine**, lying mostly posteriorly on the right side; the close coils of the **large intestine**, on the left side posterior to the stomach and spleen; the **rectum**, the terminal part of the large intestine, to be shown more clearly later; the **cecum**, a blind sac on the left side, between the small and large intestine as an extension of the large intestine beyond the entrance of the small intestine; the much fluted **mesentery**, slinging the intestines from the dorsal body-wall; the many small **lymph nodes**, in the middle of the mesentery; the long, narrow **urinary bladder**, extending posteriorly from the umbilicus, and with the two **umbilical arteries** at its sides.

Make a quick drawing of your whole dissection, naming all organs. Represent the umbilicus and urinary bladder as pulled backward.

Cut across the small intestine an inch from the stomach. Cutting the mesentery close to the intestines, carefully free both small and large intestines from the mesentery, leaving the last two inches of the rectum. Cut open two inches of the small intestine, and note the fuzzy appearance, due to the small **villi** which project into the cavity of the intestine. Slit open an inch or two of the large intestine and cecum on the side opposite the entrance of the small intestine, to get the entrance of the small into the large intestine.

The Blood-Vascular System—General Statement.—The following **general plan** of the circulatory system of mammals should be kept in mind during your dissection of the pig fetus: 1, there is a 4-chambered heart, consisting of right and left auricles, and right and left ventricles. Systemic and pulmonary circulations are separate from each other. 2, the **left ventricle** pumps only oxygenated blood through the systemic arteries to all organs of the body except the lungs. 3, blood from all parts of the body except the lungs is returned to the **right auricle**, by the precava and the postcava. All returns direct, except that from the digestive tract and spleen which

passes first to the liver by the hepatic portal vein, thence to the postcava by the hepatic veins. 4, blood passes from the right auricle to the right ventricle, thence to the lungs by the pulmonary arteries. 5, oxygenated blood is returned by the pulmonary veins to the **left auricle**, thence to the **left ventricle**, to complete the circulation.

Carefully move the muscular part of the diaphragm. Note the **aorta** arising from the left ventricle and the arching to the **left dorsally**, to course backward as the **dorsal aorta**; the **pulmonary artery**, from the right ventricle, dividing to the right and left lungs, but sending most of its blood through the **ductus arteriosis** into the aorta during fetal life. From the **aortic arch** there arise a large **brachiocephalic** artery which gives off the **right brachial** to the right fore-limb, and then divides into the right and left **common carotids** which supply most of the head region; and the left **brachial**, mostly to the left fore-limb. Turn the heart and left lung to the right and note the **esophagus** and **dorsal aorta** passing dorsal to the pleural cavity. Turn the heart toward the left and note the **precava** and **postcava** entering the right auricle.

Draw the heart and associated arteries and veins so far as studied, and add the larger branches of the dorsal aorta as you study them later.

Cut across all of the large blood-vessels a quarter inch from the heart and remove the heart. Cut across the middle of the ventricles. Make a quick drawing of the section, showing the muscular walls and cavities of the right and left ventricles. With scissors in the cavity of the right ventricle, cut through into the right auricle, noting the large **orifice** between auricle and ventricle, and the **auriculo-ventricular valves** which hang into the cavity of the ventricle. Cut across the pulmonary artery close up to its origin and cut through it into the cavity of the right ventricle. Note the three small **semilunar valves** at its base. In the same way, study the same features of the left side of the heart. What of the walls of the arteries?

The Urinogenital System. Dissect away the mesentery

and free the large intestine posteriorly. Note the large bean-shaped kidneys; a dark adrenal body at the inner border of each kidney at its anterior end; a renal artery entering the concave hilus of each kidney; a ureter leaving each kidney and entering the neck of the bladder on its dorsal side.

The Female Genital System. If your specimen is a female, cut across the left umbilical artery and pull the bladder toward the right side. Cut through the skin and pelvis on the ventral mid-line and pull the hind-limbs wide apart. Clear the neck of the bladder as it narrows into the urethra which

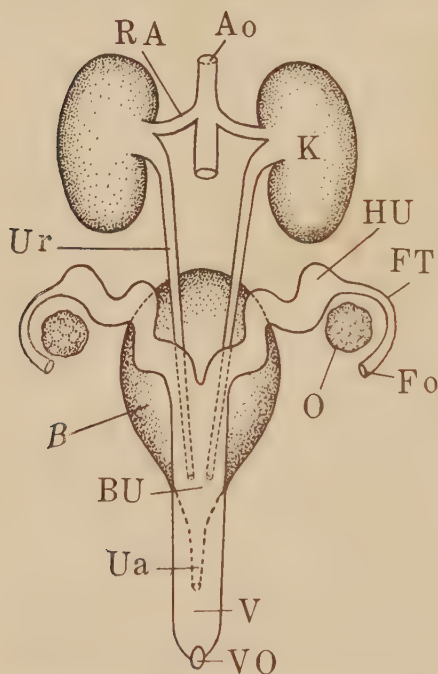


Fig. 21—Diagram of the urinogenital system of the female pig fetus, dorsal view. (Drawn by Carol Young.)

Ao, Aorta; B, bladder; BU, body of uterus; FT, Fallopian tube, the narrow anterior part of the oviduct; Fo, opening from body-cavity into the Fallopian tube; HU, horn of uterus; O, ovary; RA, renal artery; Ua, urethra; Ur, ureter, from hilus of kidney to dorsal side of bladder; V, vagina; VO, vaginal or female urinogenital opening.

passes into the ventral side of the vagina. By means of figure 21, identify the other parts of the genital system and study them carefully. Cut open the vagina and note the urethral opening into it.

Draw the female urinogenital system, dorsal view, x2.

Fig. 22
urinary duct

The Male Genital System. The general plan is well shown in these specimens. The testes, however, which are formed within the body-cavity, are still in process of passing through the body-wall into the scrotum, especially in the younger specimens. Cut through the scrotum and down to and through the pelvis an eighth inch to the left of the ventral mid-line. Cut across the left umbilical artery, and pull the bladder toward the right side. Pull the legs wide apart. By means of the figure, identify the various parts and study them carefully.

Draw the male urinogenital system, either a left lateral or a ventral view, x2.

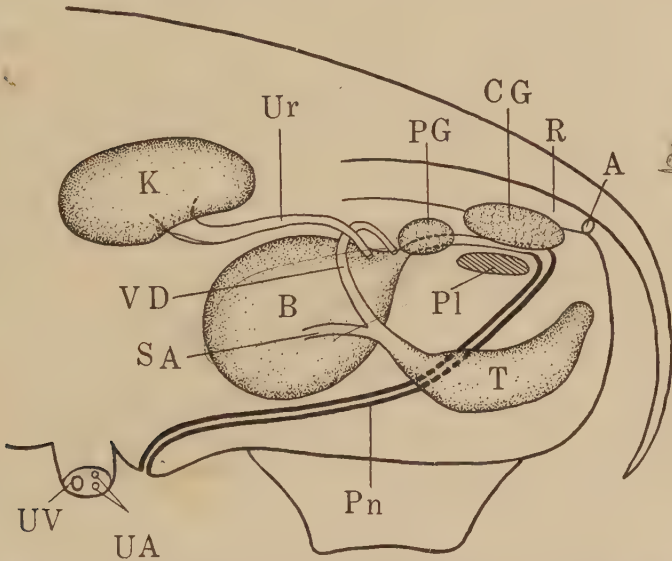


Fig. 22—Diagram of the urinogenital system of the male pig fetus, left lateral view. Of the paired organs, only those of the left side are represented. (Drawn by Carol Young.)

A, anus; B, urinary bladder; CG, Cowper's gland; K, kidney; PG, prostate gland; Pl, pelvis; Pn, penis; R, rectum; SA, spermatic artery; T, testis; UA, umbilical arteries; Ur, ureter; UV, umbilical vein; VD, vas deferens.

Now study the following larger arteries as branches of the dorsal aorta, and add them to your drawing of the heart

and arterial system: the celiac artery (to stomach, liver and spleen); the anterior mesenteric (to most of the intestines and to the pancreas); the pair of renal arteries to the kidneys. The aorta gives off the external iliac arteries (to the hind limbs), and then divides into the internal iliacs, most of whose blood goes to the umbilical arteries, which supply the embryonic part of the placenta.

The Nervous System. Cut away the dorsal skin and muscles of the skull and vertebral column; and the dorsal half of the skull and the roof of the vertebral canal throughout its whole length, so as to expose fully a dorsal view of the whole central nervous system, consisting of the brain within the skull and the spinal cord within the spinal canal. Cut away the left side of the skull to fully expose the left side of the brain, and cut down to the dorsal roots of the spinal nerves and spinal ganglia in the shoulder region. As you proceed in the skull, note the tough *dura mater* adhering to skull. It is the external membrane surrounding the brain; the thin vascular *pia mater* intimately covers the brain. These two meninges both surround the whole central nervous system, but are not so readily observed around the spinal cord. Cut away the *dura mater* from the dorsal side of the whole brain, and between the cerebrum and cerebellum.

Study the five regions of the brain: 1, the large cerebral hemispheres (telencephalon), more or less convoluted (depending on the age of the fetus), with the fissure of Sylvius running obliquely backward on either side, and the olfactory bulbs at their anterior ends; 2, the 'tween-brain (thalamencephalon), to be studied later; 3, the four rounded corpora quadrigemina of the mid-brain (mesencephalon). Their dorsal exposure is greater in the younger, less in the older fetus; in the latter gently turn the hemispheres forward and the cerebellum backward so as to show them; 4, the rather large corrugated Cerebellum, the dorsal part of the metencephalon; 5, the medulla oblongata (myelencephalon), tapering into the spinal cord. In the spinal cord, note cervical and lum-

bar enlargements (why?); the posterior end, tapering to a fine thread; the paired **spinal nerves**, corresponding in number with the vertebrae and leaving the spinal canal between the vertebrae.

Draw the whole central nervous system dorsal view, natural size; and the brain, left view, x2 or 3.

Cut out an inch or more of the cord, with the nerves and ganglia attached. Note that each **spinal nerve** is formed by the union of a **ventral (motor) root**, and a **dorsal (sensory) root** bearing the **spinal ganglion**. Make a simple diagram of a cross-section of the cord and a pair nerves to show these relations.

Cut across the spinal cord, an inch posterior to the brain, and free it forward by cutting the spinal nerves, and the cranial nerves, **close to the skull**; be especially careful to include the **pituitary body** and **olfactory bulbs** along with the brain. On the ventral side note, in addition to features already studied, the **optic nerves** arising from the ventral side of the mid-brain; the **pons**, under the cerebellum. Identify as many of the 12 cranial nerves as you can. **Draw a ventral view, x2 or 3.**

If time permits, divide the brain through the middle into right and left halves, and draw the median view of one half, naming all parts.

Now return to the thoracic cavity and note the **sympathetic nerve** on either side, just outside the dorsal aorta; the **sympathetic ganglia**, corresponding in general with the number of vertebrae.

Study of Sections. The study of sections, both longitudinal and transverse, will supplement the knowledge derived from the dissection. The following are, perhaps, the most instructive. You should be on the lookout for interesting features, especially shown in your specimens, besides those enumerated.

1. Median longitudinal section of the whole embryo. Study carefully, paying most attention to the more important

organs that are well shown, especially the five regions of the brain, pituitary body, diaphragm, etc. **Draw, x1 or 2.**

2. Cross section of the base of the neck. Note especially vertebra, spinal cord and dura mater, esophagus, trachea, thymus, carotid arteries. **Draw, x1 or 2.**

3. Cross section through the middle of the thoracic cavity. Note especially right and left ventricles, pericardium, dorsal aorta, postcava, esophagus, right and left lungs, with smaller air passages and blood vessels. **Draw, x1 or 2.**

4. Cross section through the region of the kidneys. **Draw, x1 or 2.**

CHAPTER XIII

THE ELEMENTS OF EMBRYOLOGY

The remaining weeks of the course will be given to the study of the elements of embryology of animals, as illustrated by the echinoderms, the frog, and the chick.

EMBRYOLOGY OF THE ECHINODERMS

Both because an abundance of echinoderm eggs and embryos is readily secured in all stages of development, and so beautifully illustrate the essential principles of embryonic development of all metazoa in the earlier stages, they offer the most available material for class study. The various stages in the total and equal segmentation of the egg, and the blastula and gastrula stages, are especially clearly shown. The development after the gastrula stage is peculiar to the echinoderms.

The prepared slides show stages other than those designated below, and you should interpret them so far as time permits. Up to the gastrula stage the starfish and sea-urchin or sand dollar are interchangeable for general study. In the sea-urchin and other echinoids the polar bodies are formed before the eggs are laid, are lost before the egg membrane is formed, and so will not show in the prepared slides.

In addition to the echinoderm eggs, a number of other types of "primordial ova" are studied, to accentuate the essential uniformity of general organization of the ovum in all metazoa. Also, some stages in the maturation, fertilization, and cleavage are demonstrated in the eggs of a snail (*Crepidula*), where these features are especially well shown.

Study and draw the following stages:

1. The **immature egg**. The ovum in the metazoa is always a relatively very large cell as compared with the somatic cells, usually spherical, and almost always non-motile. We shall study and draw it in a few types to show these similarities. (a), the **immature ovum** of the **starfish** is perfectly spherical in shape, with **cytoplasm**, **nucleus** containing **chromatin**, and the **nucleolus**. **Draw one**. (b), In **sections of the ovary of the frog** some of the ova, for the next batch of eggs, are very large, with the **cell-body gorged with yolk**; with a very large nucleus containing the **granular chromatin** and **several nucleoli**. Some of the ova are small and will develop into the batches of eggs of subsequent years. **Draw a large and a small one**. (c), In **sections of the ovary of a two-thirds grown cat**, there are many small ova near the outside, surrounded by follicle cells; the larger ones, to develop first, lie in the hollow "**Graffian follicles**." **Draw two of different sizes**, representing only the egg cells. (d), In **sections of the ovary of a half-grown chicken**, there are very numerous small ova near the outside, still showing as typical cells. Others are already enlarging, to become the very much modified ova (the yolk of the hen's egg). **Draw two of different sizes**.

(2.) **Maturation, fertilization, and first cleavage** in *Crepidula*. The demonstration microscopes show the following stages in the eggs of the snail *Crepidula*, which you should observe and draw: (a), the **first polar body** formed, the **second just forming**; (b), both polar bodies formed, fertilization complete, with the large **male and female pronuclei** lying alongside of each other; (c), with the **male and female groups of chromosomes** derived from the two pronuclei of the preceding stage, to be distributed to the two daughter cells at the first cleavage division; (d), the **two cells formed**, and showing three polar bodies, the first polar body having divided into two very small cells.

3. **Two-cell** stage in sand-dollar.

4. **Four-cell** stage in sand-dollar. Be sure that you have a 4-cell stage and not an 8-cell stage seen on end.

5. **Eight-cell** stage in sand-dollar. Pick out a side view that will show six of the 8 cells.

6. Early **blastula** of sand-dollar, a hollow sphere consisting of sixteen to thirty-two cells (**blastomeres**). It is not necessary to count the cells in this stage. In this and the next two stages, focus upon the middle of the embryo and draw only a middle girdle of cells.

7. Middle stage of blastula of sand-dollar.

8. Older blastula of sand-dollar.

In the last three, note the **cleavage cavity**. In the last, **oral** and **aboral poles**; at the oral pole, some of the cells migrating into the cleavage cavity to form **mesenchyme** cells.

9. Early **gastrula** of starfish. The blastula is **invaginating** at the oral pole to form the **archenteron** composed of **endoderm** cells.

10. Late gastrula. Note the outer **ectoderm**; the inner **endoderm** forming the **archenteron**; the gastrula mouth (**blastopore**).

Young Bipinnaria Larva of the Starfish. Transformation of the gastrula into the larva. In the late gastrula, a pair of small pouches are separated off from the inner end of the archenteron and lie in the primary body-cavity as a pair of small vesicles which eventually form the mesoderm, including the whole water-vascular system. The gastrula then becomes transformed into the young larva by the bending of the inner end of the archenteron to one side of the body-wall, its attachment and breaking through to the ventral side, and the formation of the larval mouth. The gastrula mouth remains as the larval anus.

Pick out a full side view of a young larva. Note **body-wall**; **hydro-enteroceles**; **digestive tract**, with mouth, gullet, stomach, intestine, anus.

Draw, 3 inches long. Also, draw as many stages in the transformation of the gastrula into the larva as your time permits.

Older Bipinnaria Larva of Starfish.—The specimens are mounted to show, some ventral view, some lateral. Note the sides and ends, and the nature of the symmetry. Note the **ventral depression**; the **body-wall**, extending into the arms; the **ciliated bands**, extending on to the arms. In the digestive tract note the large, wide-open **mouth** at the anterior end of the ventral depression; the **esophagus**, **stomach**, and **intestine**; the **anus**. In these specimens, the **hydro-enterocele pouches** have extended and become the **secondary body-cavity**, and are difficult to trace fully.

Draw a large 3-inch figure from side or ventral view.

In a side view of a still older larva note the five diverticula growing out from the left hydrocele pouch. These specimens are metamorphosing and the five diverticula are to form the radial water-vessels of the adult.

Draw from the left side.

THE DEVELOPMENT OF THE FROG.

We shall study the development of the leopard frog, as one of the interesting forms of life; and as illustrating the life-history of the tailless amphibia (frogs, toads, tree-toads, etc.) in general. Although there are differences in the sizes of the eggs, the breeding seasons, the length of the period of larval development, etc., among the various species, there is great uniformity in the general features of development.

Usually a majority of leopard frogs in our region lay their eggs during the second half of April, though some are laid earlier and many later, up to the middle of May. The time varies greatly with the season, being earlier with an earlier spring, and much delayed with a late, cold spring. During the breed-

ing season frogs of both sexes congregate in places favorable for egg-laying and the development of the eggs and tadpoles. This is usually the shallow (a foot or less in depth) water near the edges of ponds and lakes. For a day or more before the eggs are laid, the male is carried on the back of the female. Then, as the eggs are extruded in the course of a half hour or so, the sperm cells of the male are cast over and fertilize them. All of the eggs for the whole year are laid at one time in a single batch of 2,000-8,000 (depending on the size of the female), in a jelly mass.

When laid, each egg is a single cell. This divides into 2, these into 4, 8, 16, etc., so that eventually the tadpole or frog consists of myriads of cells, differentiated into the tissues which form the organs of the animal. The egg hatches in from 4-5 days to 15-20 days, depending sharply on the surrounding temperature. For a few days after hatching, the tailless tadpole clings to the jelly from which it has hatched, by means of a pair of suckers at the sides of the mouth. After the tail develops, the tadpole swims about freely, in mode of life and organization essentially like a fish. In this way it lives and develops till late in June or early in July, when, in the course of a week or two (depending sharply on temperature), it metamorphoses into the adult form. In this week or two it has undergone very profound changes, for it has changed from a fish-like, gill-breathing vegetarian living among and upon the vegetation of the muddy bottom, to an air-breathing **amphibious** animal swimming in the water, or jumping among the vegetation on land in search of insects and other prey.

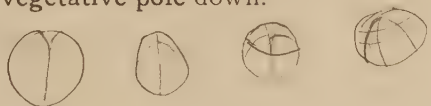
Study and draw the following stages, the eggs and tadpoles in side view, the stages of metamorphosis in dorsal view:

1. **One-cell stage.** Draw an inch in diameter, with the black animal pole up and the light vegetative pole down.

2. **Two-cell stage.**

3. **Four-cell stage.**

4. **Eight-cell stage.**



5. Sixteen or thirty-two cell stage.

6. Tadpole just hatched, x8.

7. Tadpole two or three days old, x8. Note eyes; the tufted gills; the pair of suckers at the sides of the mouth.

8. Tadpoles a half inch in length, a week or ten days old, x8. In this stage the gills have been overgrown by folds, and there is a single respiratory opening on the left side. Note further: nostrils; horny beaks; anus.

9. An inch and a half long, six weeks old, x1.

10. Full grown tadpole, eight or ten weeks old, x1. With this stage, in addition to a side-view drawing, expose the brain from the dorsal side and draw, x 6. Remove the covering of the gills on the ventral side of the throat so as to show the gills and gill-slits; dissect off the thin body-wall, so as to expose the coiled intestine, heart and other organs. Draw the whole animal, as now dissected, ventral view. Uncoil the intestine, measure, compare with the length of that of the adult frog, and make note of your observations. Identify as many as you can of the organs which you found in the adult.

11. Three stages of metamorphosis, x1; a, with full-grown tail and two pairs of limbs; b, with tail about half absorbed; c, with tail almost absorbed.

Review the changes that have taken place during metamorphosis, and make note of all that you have found.

If you have time, the metamorphosis of the toad and salamander may be studied also.

THE EMBRYOLOGY OF THE CHICK

The laboratory work for the remaining weeks of the course will be devoted to a study of some of the general principles of embryonic development of the higher vertebrates, as illustrated by the embryology of the chick. The chick is chosen, partly because it clearly shows and typifies most of

the general features of development of the higher vertebrates, partly because chick embryos in the desired stages of development are readily secured and prepared for study. The laboratory work will include the subjects as outlined below and will follow the time and order as given. In addition, several demonstrations will be given on the living embryos for some features not at all, or not well, shown in preserved specimens.

Please observe the following:

1. The fingers should not touch the surface of the cover glass of the prepared slides and the microscope clips should not press upon it.

2. The embryos of 24, 30, 55, and 72-96 hours are mounted as whole objects for microscopic study; from five days on they have the amnion dissected away and are to be examined in liquid.

3. For the 30 and 55-hour stages, in addition to the whole mounts, each student is supplied with an embryo cut into a series of sections, the whole series mounted in order on a single slide.

4. In studying the sections, use colored pencils to make large diagrammatic drawings. Use green for all parts derived from the ectoderm, red for all parts derived from the mesoderm, and blue for all parts derived from the endoderm.

5. A number of copies of Patten's "Embryology of the Chick" will be distributed about the laboratory for reference use. They may be used at any time during laboratory hours, but must in no case be taken from the laboratory. These texts will be referred to in these Directions as "P." for Patten. Constant reference should also be made to the figures in the Directions.

FIRST DAY

Study of Whole Mounts of 30-36 Hour Stage

The blastoderm of this stage has grown to be a thin disc,



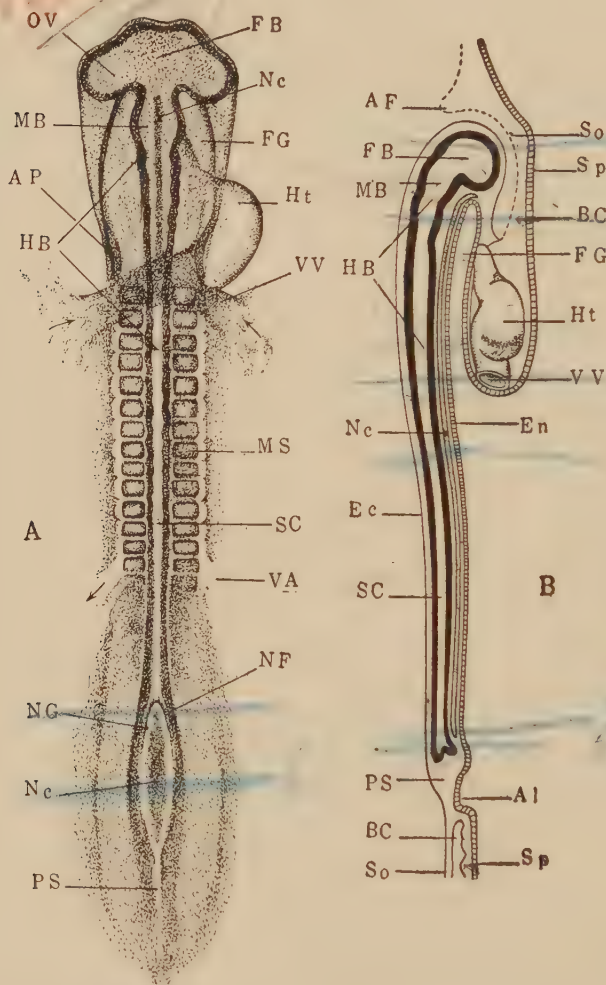


Fig. 23 A.—Chick embryo of 32 hours' incubation, dorsal view, examined as a transparent object. $\times 25$. The outlying parts of the blastoderm are omitted.

B.—A diagrammatic median longitudinal section of a 36-hour chick embryo. $\times 20$. (After Marshall.)

AF, amniotic fold; Al, allantois; AP, auditory pit; BC, body-cavity (in the upper part of Fig. B, the index line BC should extend into the space to the left); Ec, ectoderm; En, endoderm; FB, embryonic fore-brain vesicle; FG, fore-gut; HB, hind-brain, composed of several sec-

ondary vesicles; **Ht**, heart; **MB**, mid-brain; **MS**, mesodermal somite; **NF**, neural fold; **NG**, neural groove (where the neural folds have not yet fused to form the neural tube); **Nc**, notochord; **OV**, optic vesicle; **PS**, primitive streak; **SC**, spinal cord (neural tube); **So**, somatopleure; **Sp**, splanchnopleure; **VA**, vitelline arteries; **VV**, vitelline veins.

about three-quarters of an inch in diameter, and lies like a watch-glass upon the upper surface of the yolk, dorsal side up. This disc has been stripped off the yolk and mounted, some specimens dorsal side up, some ventral. In most cases not all of the outer thin edge of the blastoderm has been mounted and a paper ring, used in previous manipulation, has been left on in mounting the specimen. Most of your examination of this stage will be made with the dissecting microscope and the lower power; the higher power should be used only with great caution.

P., Figs. 21-24; Fig. 23 in Directions.

With the unaided eye note the following very general features: the **embryo** proper, the narrow dark streak in the center of the blastoderm; the transparent **area pellucida**, immediately surrounding the embryo; outside the latter the **area opaca**, of which the deeply-stained inner part is the **vascular area**, in which blood-vessels are developing.

Make a quick simple drawing to show these general features, x 2.

Study the dorsal view with low power, referring to Figs. 23 and 24. Note the head, jutting out above the underlying membrane. The **nerve tube**, enclosing the **neural canal** is closed in front. It is continued behind into the open **neural plate**, with the **neural groove** in the mid-line and the **neural folds** at the sides still continuous with the surface ectoderm. The anterior end of the nerve tube is specialized into a series of **brain vesicles**: 1, the **fore-brain vesicle**, with a pair of **optic vesicles** growing out as diverticula at its sides. (From the fore-brain vesicle the cerebral hemispheres will grow out anteriorly after the second day; the original fore-brain vesicle will

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develop into the 'tween-brain of the adult; the optic vesicles, on either side will become the retina and pigment layer of the eye); 2, the **mid-brain vesicle**, to develop into the mid-brain of the adult. 3, the **hind-brain vesicles**, a series of smaller vesicles, to develop into the cerebellum and medulla oblongata of the adult. The neural plate is continued posteriorly into the **primitive streak**. The **notochord** is shown as a wide band ventral to the posterior, unclosed portion of the neural plate and extends forward as a clean-cut streak as far as the fore-brain vesicle.

—Note the **ectoderm**, covering the head on its outside. The **mesoderm** fills the space at the sides of the nerve tube. It is undivided in front, but posteriorly is divided into a variable number (depending on age) of **mesodermal somites**, which are increasing in number posteriorly. At either side of the somites the **lateral plate** of the mesoderm is unsegmented.

Note the **heart**, on the right ventral side, receiving a pair of large, lateral **vitelline veins** posteriorly and giving off a single, ill-defined **ventral aorta** in front. The crescentic fold posterior to the heart marks the posterior end of the digestive tube formed by the head fold of the splanchnopleure.

Make a drawing six or more inches long to show the features of your embryo, omitting the outlying parts.

Study the ventral view and draw if you have time.

SECOND AND THIRD DAYS

Study of Transverse Sections of 30-36-Hour Stage

P., Fig. 28E; also Fig. 24 in the Directions.

Pick out a typical section from about the middle of the series, such as is shown in Fig. 24, and note the following: **nerve tube** with **neural canal** in its center; the **notochord**; the triangular **mesodermal somites** at the sides of the nerve tube; the **ectoderm** dorsally and the thin **endoderm** ventrally; lat-

eral to the mesodermal somite, the mesoderm split into two laminae, the dorsal part forming with the ectoderm the **somatopleure** and the ventral part forming with the endoderm the **splanchnopleure**; the potential **body-cavity** between the somatopleure and splanchnopleure; the dorsal **aortæ** (paired at this stage) at the sides of the notochord; the **smaller blood-vessels** in the mesoderm of the splanchnopleure.

Make a large figure with colored pencils to show what you have found.

Now study and draw the additional sections indicated below, labelling all structures in each section. Refer con-

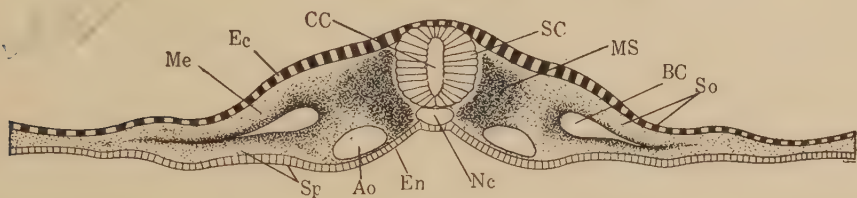


Fig. 24—Transverse section of a 32-hour chick through a pair of mesodermal somites about the middle of the embryo, somewhat diagrammatic. $\times 75$.

Ao, aorta; **BC**, body-cavity; **CC**, central canal (neural canal); **Ec**, ectoderm; **En**, endoderm; **Me**, mesoderm; **MS**, mesodermal somite; **Nc**, notochord; **SC**, spinal cord (neural tube); **So**, somatopleure; **Sp**, splanchnopleure.

stantly to Fig. 23 in the Directions and to your own figure of the whole embryo.

1. Section through the optic vesicles. Under the head the blastoderm consists of only ectoderm and endoderm in the middle; laterally mesoderm is present also. See P., Fig. 28A.

2. Section through the head posterior to the optic vesicles, showing especially the flattened **pharynx** under the notochord. P., Fig. 28B.

3. Section through the heart, noting the thick wall of the heart and its thin lining inside. P., Fig. 28C.

4. **Section just posterior to the heart**, showing the folds of splanchnopleure coming together to form the digestive tube. Note as special features the **vitelline veins** at the sides; the **auditory pits** as thickened, depressed ectoderm at the sides of the nerve tube and destined to form the **auditory vesicles** of the next and later stages. P., Fig. 28D.

5. **Section near the posterior end**, showing the neural folds coming together to fuse to form the nerve tube. The **body-cavity** is only a slight cleft in the mesoderm, but should not be overlooked.

6. **Section showing the neural plate** as a thickened, depressed area of the ectoderm.

7. **Section through the primitive streak**. The thickening in which the ectoderm, notochord and mesoderm are indistinguishable is the **primitive streak**. The depression of the ectoderm is the **primitive groove**.

With the knowledge obtained from your study of the transverse sections, make any corrections necessary in your drawing of the dorsal view of the whole embryo. By neat, sharp lines across this drawing, indicate the plane of the sections from which your drawings were made, numbering them corresponding to the figures of the sections.

FOURTH DAY

Study of Whole Mounts of the 55-Hour Stage

See Figs. 25 and 26; P., Figs. 35 and 36.

These specimens in the various slides vary from 50-60 hours. They have lost, in part or wholly, that part of the area opaca outside the vascular area, during preparation. They are mounted dorsal side up, the position occupied naturally in the egg on top of the yolk.

With the unaided eye study the very general features, as in your study of the 30-hour stage, and make a small, simple drawing to show what you find, x 2.

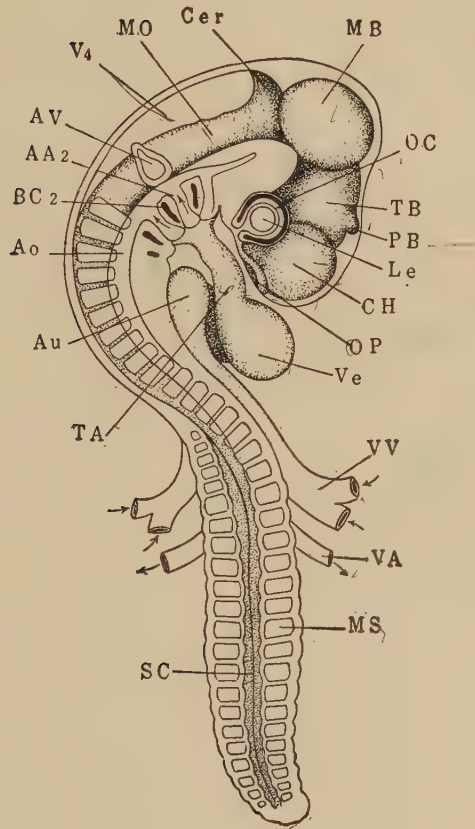


Fig. 25—Chick embryo near the middle of third day of incubation. The twisting of the embryo has progressed to the middle of the body, so that the anterior half is seen from the right side and the posterior half from the dorsal surface. The amnion is not represented in the figure. The arrow heads indicate the direction of the blood flow. $\times 20$. (After Marshall.)

AA2, second aortic arch; **Ao**, aorta; **Au**, auricle of the heart; **AV**, auditory vesicle; **BC2**, second branchial cleft; **Cer**, cerebellum; **CH**, cerebral hemisphere; **Le**, lens of eye; **MB**, mid-brain; **MO**, medulla oblongata; **MS**, mesodermal somite; **OC**, optic cup of the eye; **OP**, olfactory pit; **PB**, pineal body; **SC**, spinal cord; **TA**, truncus arteriosus of heart; **TB**, 'tween-brain; **VA**, vitelline artery; **Ve**, ventricle of heart; **VV**, vitelline veins; **V4**, fourth ventricle of brain.

The **head** has turned so as to lie upon its left side, the posterior half of the embryo is still dorsal side up. The **head-fold** has pulled back to a third or a half of the length of the embryo. Over the head the **amniotic fold** has grown dorsally and posteriorly, and its posterior border is shown as a crescentic curve across the dorsal side of the embryo, a third or a half of the distance from its anterior end. At the posterior end of the older specimens, the **tail fold** has appeared, causing the posterior end of the embryo to jut out more or less as the forming tail above the outlying blastoderm. Note, as other conspicuous features, the large **heart** on the ventral side; dorsal to the heart on each side the three sharply defined, narrow **gill-clefts**, with the **gill-arches** between them.

Note
The nervous system and sense organs lead the way in embryonic development and in the 55-hour stage have advanced much beyond their development of the 30-36 hour stage. The nerve tube is specialized into the brain with four clear-cut regions in front, and the spinal cord posteriorly. Note, as parts of the brain, the large single vesicle anteriorly, grown forward as a diverticulum of the fore-brain vesicle and later to develop into the **paired cerebral hemispheres**; the 'tween-brain, the **original fore-brain vesicle**; the **mid-brain**, from the mid-brain vesicle; the dorsal side of the hind-brain vesicle just beginning to specialize anteriorly as the **cerebellum**; the remainder to form the **medulla oblongata**, already thin-roofed. The cavity in the first vesicle will grow out at the sides as the **right and left ventricles** in the right and left cerebral hemispheres; the cavity in the 'tween-brain will become the **third ventricle**, and that in the medulla, the **fourth**.

The **optic vesicles** have greatly enlarged and have invaginated, so as to become double-walled **optic cups**, the walls in surface view giving the appearance of two horsehoes, one within the other. The **lens** of the eye is a vesicle almost or wholly tucked off from the surface ectoderm and lies as if it had pushed in the optic vesicle.

Just dorsal to the gill-slits on each side is the more or less



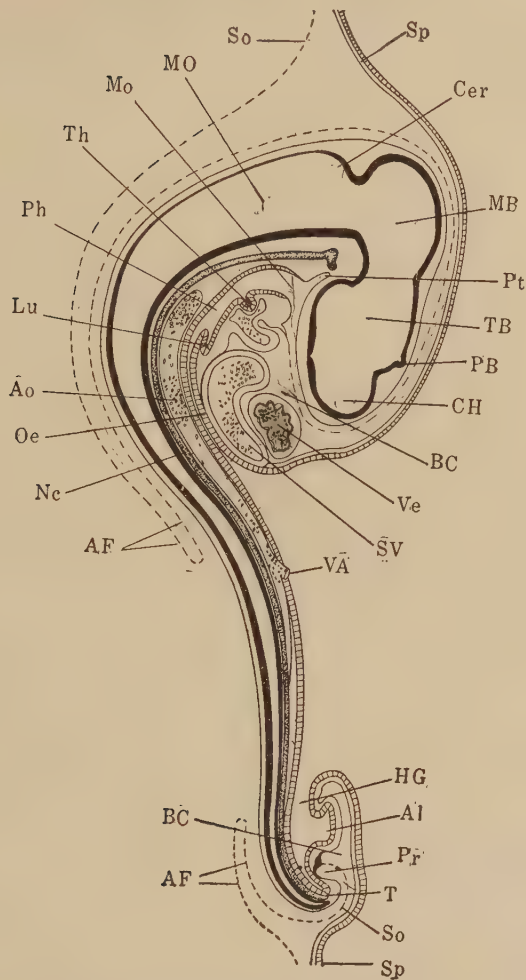


Fig. 26—A diagrammatic median longitudinal section of a 3-day chick embryo. The fold of the somatopleure forming the amnion is represented by dotted lines. $\times 20$. (After Marshall.)

AF, amniotic fold; Al, allantois; Ao, aorta; BC, body-cavity; Cer, cerebellum; CH, cerebral hemispheres; HG, hind-gut; Lu, rudiment of lung; MB, mid-brain; Mo, mouth; MO, medulla oblongata; Nc, notochord; Oe, esophagus; PB, pineal body; Ph, pharynx; Pr, proctodeum (an invagination which will break through into the hind-gut to form the anus); Pt, pituitary body; So, somatopleure; Sp, splanchnopleure; SV, sinus venosus; T, tail; TB, 'tween-brain; Th, rudiment of thyroid gland; VA, vitelline artery; Ve, ventricle.

spherical **auditory vesicle**, formed as an invaginated thickening of the ectoderm and still connected with the exterior by a small pore near its dorsal side. It will form the whole sensory part of the auditory organ.

At the sides of the nerve tube posteriorly the **mesodermal somites** are clearly shown as paired structures. Anteriorly in the twisted part of the embryo only those of the right side are visible. Ventral to the nerve tube the **notochord** is more or less clearly shown, extending forward as far as the anterior end of the mid-brain.

The heart forms a twisted, more or less S-shaped structure. The large part next to the body of the embryo, and on its left side is the **auricle**; the part that dips ventrally is the **ventricle**. From the ventricle the **ventral aorta** arises and breaks up into (in this stage) **first, second and third pairs of aortic arches** which may be traced through the gill arches by means of the granular appearance given by the contained blood corpuscles. The aortic arches unite to form the **dorsal aorta**, single anteriorly, paired posteriorly, and lying ventral to the mesodermal somites. The pair of transverse vessels leaving the embryo a third of the distance from the posterior end are the **vitelline arteries**; the **vitelline veins** entering the auricle more anteriorly, are not so sharply defined.

Make a 6-inch figure of the embryo proper to show all you have made out in your study.

FIFTH AND SIXTH DAYS

Study of Transverse Sections of the 55-Hour Stage

P., Fig. 37E; and Fig. 27 in Directions.

First choose a section showing the amniotic fold as illustrated in Fig. 23, and study the features indicated below: the **nerve-tube** (spinal cord in this region); **notochord**; **mesodermal somites** (the mesoderm under the part marked "MS" is also a part of the mesodermal somite); **dorsal aorta**, still paired

in this region; **Wolffian duct**, a small, thick-walled tube on the outer side of the mesodermal somite, the excretory duct of the embryonic kidney.

In this section you should get a sharp idea of the following: the **ectoderm** as an outer, dorsal layer of cells; **endoderm** as an inner, ventral layer (very thin in the region of the embryo, thicker in the outlying regions of the blastoderm); **mesoderm**, forming all between ectoderm and endoderm except

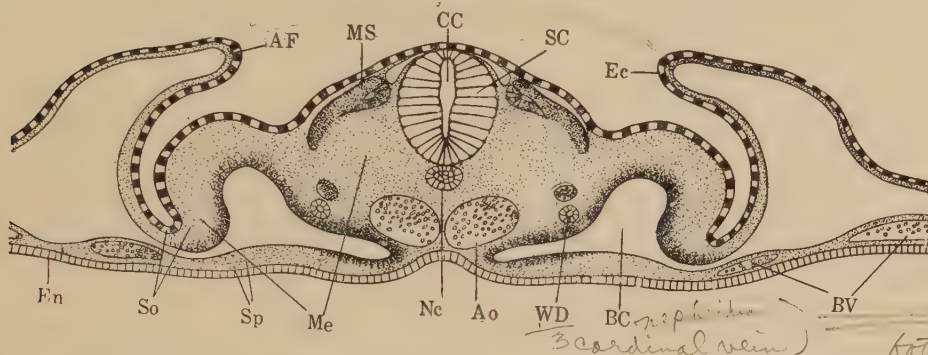


Fig. 27—Transverse section of a 52-hour chick through the third quarter. x75.

AF, amniotic fold; Ao, aorta; BC, body-cavity; BV, blood vessels; CC, central canal of spinal cord; Ec, ectoderm; En, endoderm; Me, mesoderm; MS, mesodermal somite; Nc, notochord; SC, spinal cord; So, somatopleure; Sp, splanchopleure; WD, Wolffian duct (of the embryonic kidney).

the nerve-tube derived from the ectoderm; **somatopleure**, consisting of **ectoderm** and dorsal lamina of the **mesoderm** fused, and destined to form the body-wall of the adult; **splanchnopleure**, **endoderm** and ventral lamina of the **mesoderm** fused, and destined to form the wall of the digestive tube; **body-cavity**, the space between somatopleure and splanchopleure, destined to be the body-cavity of the adult.

Make a careful large drawing with colored pencils.

Study and draw the additional sections indicated below, omitting the embryonic membranes, except in No. 5. A good many small blood-vessels and other details may be over-

looked in your study. Refer constantly to Figs. 25 and 26 in the Directions, and to your own figure of the whole embryo, for the identification of the features of the sections.

✓ 1. **Near the anterior end** of the arch of the head, through mid- and hind-brain. *Chorion, amnion, 4th ventricle*

✓ 2. **Section through the eye**, showing the lens as a **thickened invagination** of the surface ectoderm and still opening to the exterior. This section may show the **pharynx**, with the first pair of **gill-clefts** as outpouchings from it. Depending on the age, the **auditory vesicles** may or may not show in this section. If not shown in this section, study a separate section for them, representing one of the vesicles and adjacent parts in a separate drawing. Also, if the pharynx with the gill-clefts is not shown in this section, study and draw a section that shows it. See P., Figs 37A and B; Fig. 28 in Directions.

3. **Section through the heart**, in which the **auricle** (dorsally) and **ventricle** (ventrally) are shown as separate sections. In this section the splanchnopleure has formed the closed digestive tube, but the somatopleuric folds are still wide open and will not close in around the heart and form the body-wall till a day or two later. P., Fig. 37C.

4. **Section showing the digestive tube forming** by the closing together ventrally of the splanchnopleure of the two sides.

(5.) **Section showing the amniotic folds fused together dorsally**, thus forming the **amnion** inside next the body of the embryo, enclosing the **amniotic cavity**; and the **chorion** on the outside. P., Fig. 37D.

6. **Section in the tail region** showing the splanchnopleure folding ventrally and towards the mid-line from the sides to

form the posterior part of the digestive tube. The various slides vary widely. In some the tail has been distinctly formed. This section may be through the posterior part of the nerve tube, or behind it and through the primitive streak.

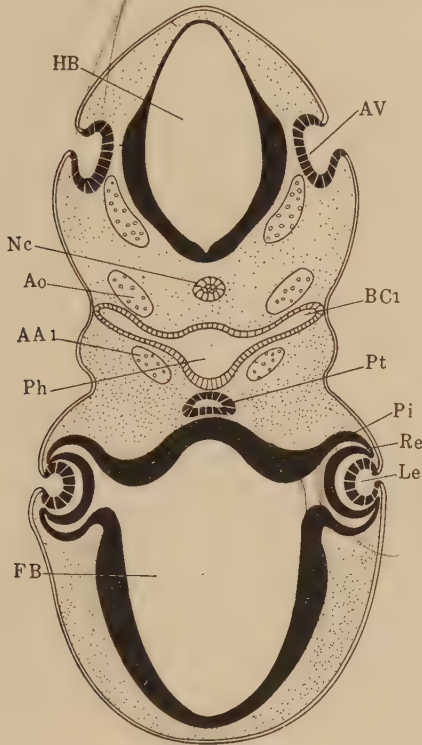


Fig. 28—A slightly diagrammatic section through the head of a 52-hour chick embryo, to show especially the early development of the eye and internal ear. The auditory and lens vesicles are still clearly open to the exterior, and show their derivation from the ectoderm of the surface. x50.

AA1, first aortic arch; Ao, aorta; AV, auditory vesicle; BC1, first branchial cleft; FB, embryonic fore-brain vesicle; HB, embryonic hind-brain vesicle, showing the already very thin dorsal wall of the medulla oblongata; Le, lens of the eye, forming as an invagination of the surface ectoderm; Nc, notochord; Pi, the outer layer of the optic cup, which will form the pigment layer of the eye; Ph, pharynx; Pt, pituitary body; Re, the inner layer of the optic cup, which will form the retina.

SEVENTH DAY

Study of Whole Specimens of Early and Later Stages

This day's work, together with your previous study of the whole mounts of the 30 and 55-hour stages, is intended to give a general running account of the broad outlines of development. **Carefully study and draw the stages indicated and name all parts in all of the figures.**

1. **The 24-hour stage.** P., Figs. 15 and 17. The slides given out will vary from 22-26 hours, so that the earliest and latest stages will depart somewhat from the directions given below.

Note the **head**, just beginning to jut out dorsally above the underlying blastoderm; the **neural folds**, just coming together dorsally in the region that will form the brain, and passing posteriorly into the depressed **neural plate**; the **vertebral plate** of the mesoderm, anteriorly broken up into several **mesodermal somites**; in the mid-line, the **notochord** as a faint streak; posteriorly the **primitive streak** and on its dorsal side the **primitive groove**. The crescentic curve ventrally under the head marks the posterior end of the head-fold of the splanchnopleure; the point at which the covering ectoderm of the head fades out at the sides marks the posterior limit of the head fold of the somatopleure.

Make a figure 3-4 inches long.

2. **The 3-4 day stage.** P., Figs. 43 and 44. **There are considerable differences among these slides.** In the 3-day stage the anterior part only lies on its left side; in the 4-day stage the embryo lies completely upon its left side. The amniotic folds have almost or wholly closed in from anterior and posterior ends and from the sides, in the 3-day stage. The amnion is a clearly closed sac in the 4-day stage.

Note, as more special features, the paired **cerebral hemispheres**; the **nasal pits**, ventral to the cerebral hemispheres;

four gill slits; the gill arch in front of the first, differentiating into the upper and lower jaws; the two pairs of limbs as long thickenings; the tail, shown distinctly; the anterior end of the tail-fold shown as a crescentic line near the posterior end. In the 4-day embryo the allantois juts outside the embryo proper as a spherical vesicle on the ventral side at the posterior end.

Make a small 2-inch figure of the whole blastoderm for the very general features; and a 4-inch figure of the embryo proper for details, representing only the embryo and not the membranes in the large figure.

3. The 5-6-day stage. In these and later stages the embryonic membranes have been removed and the embryo separated from the outlying blastoderm at the yolk-stalk. In this stage the embryo is still of a generalized type and might represent fairly well the embryo of any of the higher vertebrates—reptile, bird or mammal. The mid-brain is especially large in bird embryos at this stage.

Draw, $\times 4$.

4. The 8-9-day stage. In this stage the embryo is distinctly of the bird type.

Draw, $\times 4$.

5. The 10-15-day stage. In this stage the embryo has attained essentially the final adult form.

Draw, $\times 4$.

EIGHTH DAY

The Development of the Eye

Figs. 28 and 29 in Directions

General Statement.—Carefully master the plan of the adult eye as shown in Fig. 29, before you begin your study of the development of the eye. The general features to be kept especially in mind in studying the development of the eye are:

the derivation of the pair of optic vesicles from the first brain vesicle; the derivation of the pigment layer and the retina from the optic vesicle; the formation of the lens from the surface ectoderm and its specialization into the outer lens epithelium and the lens fibers; the differentiation of the mesoderm surrounding the optic cup into choroid and iris, and into sclerotic and cornea; and the formation of the eye-lids as folds of the skin over the eye-ball. You should refer constantly to the accompanying diagram of the eye, to understand better the relations of the parts.

The figures already made of the developing eye of the 30- and 55-hour stages should be brought into this study and

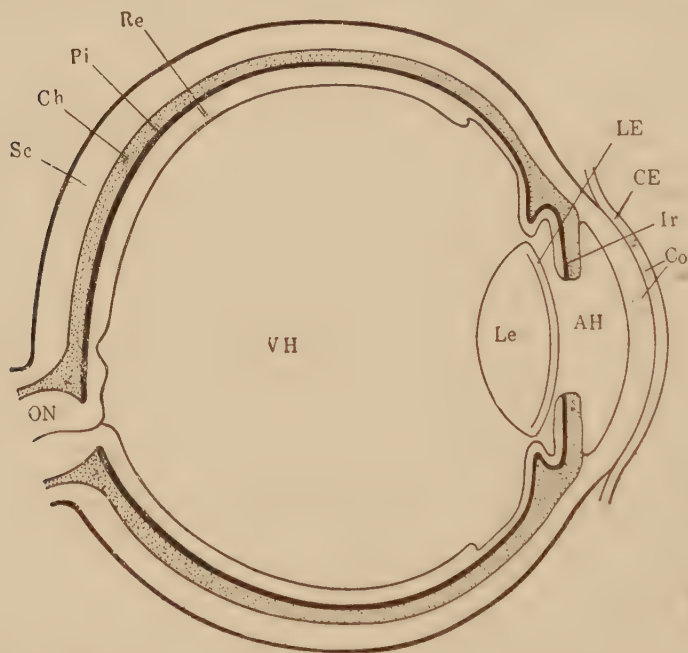


Fig. 29—Diagrammatic vertical section of the human eye.

AH, anterior chamber, filled with aqueous humor; CE, epithelium covering the cornea; Ch, choroid; Co, cornea; Ir, iris; Le, lens; LE, lens epithelium; ON, optic nerve; Pi, pigment layer of the eye; Re, retina; Sc, sclerotic; VH, cavity filled with vitreous humor.

be made the first two figures for the development of the eye. The special slide for the study of the development of the eye contains a single section cut vertical to the surface from each of the 3-, 4-, 5-, 7-, 9-, and 13-day embryos.

Study and draw the stages indicated below. Your figures should be large and sharp, representing only the parts concerned in the formation of the eye and not the rest of the section. Represent the parts derived from the optic vesicle in green, from the lens vesicle in brown, and from the mesoderm in red. Label all essential parts in all of the figures.

1. Section through the optic vesicle and the surface ectoderm adjacent to it, from the 30-hour series.

2. Section from the 55-hour series, showing the lens forming from the surface ectoderm, but still in open connection with the outer surface. The optic vesicle has invaginated just inside the lens to form the optic cup which has already differentiated into an inner thicker layer destined to form the retina, and an outer thinner layer, to form the pigment layer. The mesoderm forms a loose, undifferentiated tissue surrounding the eye.

3. The 3-day stage. In this and subsequent stages the section may or may not pass through the optic stalk which connects the optic cup with the brain. The lens has been separated from the surface and the surface ectoderm overlying it will later form the epithelial covering of the cornea.

4. The 4-day stage. P., Fig. 46C. The inner wall of the lens vesicle has thickened so as to obliterate, more or less, the cavity of the lens vesicle and its cells are elongating to form the lens fibers of the adult lens. The outer wall of the lens vesicle will become the lens epithelium on the outer face of the lens. The cavity of the optic cup inside the lens will form the cavity of the vitreous humor.

5. The 5-day stage. In most cases a very thin layer of mesoderm cells has migrated under the ectoderm outside the

lens, and is destined to form the inner, thicker, **fibrous layer** of the **cornea**. If you have time, draw the details of one half of the lens.

6. **The 7-day stage.** Note, as special features, the edges of the optic cup and overlying mesoderm cells beginning to grow over the outer edges of the lens, to become the **iris**; the developing **anterior chamber** of the eye between the lens and the cornea; the mesoderm around the optic cup concentrating slightly and destined later to differentiate into **choroid and sclerotic coats**; the mesoderm cells forming a distinct layer under the surface ectoderm outside the lens and destined to form the **fibrous part of the cornea**.

7. **The 9-day stage.** In this and in the next stage the pigment layer is more or less separated from the retina by an artificial space which should be eliminated in your drawings. Likewise, the crinkles in the retina are distortions, due to the preparation of the sections. The choroid coat is shown in section as a very thin layer between the sharply defined black line of the pigment layer and the sclerotic, which forms a narrow band of cartilage. The eye-lids are just forming as folds of the skin. In this and the next stage the **pecten** extends into the posterior chamber of the eye. It is of mesodermal origin and is not found in the eye of man and other mammals.

8. **The 13-day stage.** In the lens there is an artificial space between the lens epithelium and the body of the lens. In this stage the form and relations of the parts of the adult bird eye have been essentially established.

NINTH DAY

The Development of the Vertebrate Plan of Structure

See Patten's Figs. on p. 158.

This series is intended to show especially the **derivation**

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of the vertebrate plan of structure by the ventral folding, closing in, and differentiation of the somatopleure to form the body-wall, and of the splanchnopleure to form the wall of the digestive tube, the space between becoming the body-cavity. In the later stages many minor features of structure may be neglected.

The special slide for this study contains a cross section of the trunk region from each of the 2-, 3-, 4-, 5-, 7-, 9-, and 13-day embryos.

Study and draw the series, omitting either the 9- or 13-day stage if you have not time for all. Label all essential parts in all of your figures.

1. The 2-day stage. Fig. 27 in Directions.

2. The 3-day stage. The amniotic folds have met and fused dorsally, forming the **amnion** next to the body, enclosing the **amniotic cavity**; and the **chorion** outside. The forming embryonic kidney has been specialized into **Wolffian duct** and **Wolffian body**, the denser mass just inside it. Note also the beginning differentiation of the periphery of the spinal cord into **white matter** and the partial growth around the spinal cord and notochord of the mesoderm destined to form the **vertebral column**.

3. The 4-day stage. This section is through the doubled embryo and shows both head and trunk regions. Only the trunk is to be studied and drawn, and the embryonic membranes are to be omitted. The **intestine** is shown as a closed tube in most of the sections, but in some, taken in the region of the yolkstalk, the folds of the splanchnopleure have not yet come together to form the tube. The greatly thickened lining of the body-cavity just inside the Wolffian body is the **germinal epithelium** and will develop into the reproductive organs (ovaries or testes), shown in some sections of the later stages. The large veins at the sides of the aorta are the **cardinal veins** and those in the splanchnopleure are the **vitelline veins**.

4. **The 5-day stage.** The **Wolffian bodies** are large, loose structures, showing many tubes in section. In some of the sections the **reproductive organs** are shown as compact structures inside the **Wolffian bodies** and the **lungs** as a pair of tubes at the sides of the digestive tube.

5. **The 7-day stage.** The mesoderm around the notochord and spinal cord is forming **cartilage**; the reproductive organs are shown on one or both sides as compact bodies on the inner ventral side of the **Wolffian bodies**; the **liver** is a very large, rather loose organ; the digestive tube is cut variously in the different slides.

6. **The 9-day stage.** The heart is shown in some of these sections.

7. **The 13-day stage.**

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